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MONTHLY WEATHER REVIEW

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions, and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological tables, dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; (*b*) abstracts or reviews of important meteorological papers and books; and (*c*) notes. In each issue of the REVIEW abstracts, reviews, and notes are grouped by subjects, roughly, in the following order: General work, observations, and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but **the publication of contributions is not to be construed as official approval of the views expressed.**

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. *Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.,"* in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW OR SUPPLEMENTS.

The section of the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
Meteorological and Seismological Service of Mexico.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS, containing kite observations, and others containing monographs or specialized groups of papers, are published from time to time

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NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement, some experimental results and a theory—each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. The attached addressed franked slip may be used for this purpose, or one may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.
1915: May, June, July, August.
1916: January, August.
1917: June.
1918: February, September.
1919: Any issue, especially November
1920: Any issue, especially January.

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

VOL. 48, No. 11. NOVEMBER, 1920. CLOSED JAN. 4, 1921
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FLYING WEATHER IN THE SOUTHERN PLAINS STATES.

BY JOHN A. REIHLE, METEOROLOGIST.

[Aerological Station, Broken Arrow, Okla., November 18, 1920.]

SYNOPSIS.

This paper is a study of wind and weather as they affect the business of flying. Tables of average free-air winds have been computed for the first two years of pilot balloon observations at Broken Arrow and Fort Sill, Okla., and for one year at Fort Omaha, Nebr. The annual means are based on 1,237 observations at Broken Arrow, 1,098 at Fort Sill, and 567 at Fort Omaha. By applying to the mean velocities the mean gradients from each level to the next higher level from the surface up, discontinuities due to fewer observations at higher altitudes have been to a large extent eliminated. Average directions were computed separately by trigonometry.

Because balloon ascents are made at times when the wind is too light for kite flights, a comparison of mean velocities obtained by kites and balloons shows a slightly smaller mean velocity in summer by balloons. Another fact brought out is that the direction at high altitudes at both Oklahoma stations has a stronger northerly component in summer than in any other season.

The general eastward drift of the air at high altitudes is conspicuous at all stations; marked differences, however, occur from time to time under similar surface pressure distribution, and these differences are largely the result of abnormal surface temperatures.

Velocities in the free air are somewhat smaller over Oklahoma than at stations farther north and this fact, together with the comparatively mild winters, is favorable for the growth of aviation in this region. Transcontinental flying, too, can be continued throughout the year at this latitude while a considerably more northerly route would often be closed by inclement weather.

Low clouds and rain constitute the most frequent unfavorable condition for flying; fog is serious, but too infrequent to be of importance; while high winds are of intermediate importance.

INTRODUCTION.

The economic importance of the wind in commercial aeronautics calls for complete data on this meteorological element based on a systematic distribution of regular observations. This work was started years ago in this country, but received added impetus when wind observation by means of pilot balloons was begun by the Signal Corps during the war. These observations are now conducted by the Weather Bureau as a part of the permanent work of aerological investigations. The records have added much to our knowledge of the seasonal and geographical distribution of the winds in the free air, and will be of increasing value with the growth of aviation.

Pilot balloons furnish, perhaps, the most available method for measuring the wind aloft for flying purposes, their usefulness being precluded only by the conditions that interfere with flying, namely, fog, low clouds, and precipitation. They have the advantage over kites in that either very high or very low velocities may be measured, while kites can not rise through a calm stratum and are blown away if the wind is too strong. Furthermore, the data are quickly available after the observation is made.

AVERAGE WINDS ALOFT.

The means of velocity and direction for Broken Arrow and Fort Sill, Okla., and Fort Omaha, Nebr., are given in Tables 1, 2, and 3. Broken Arrow records are for the period November, 1918, to October, 1920, inclusive; Fort Sill, for July, 1918, to July, 1920; and Fort Omaha, for December, 1918, to November, 1919. The number of observations for each season and for the year on which Tables 1 to 3 are based is given in Table 4. Broken Arrow records were computed to an altitude of 6,000 meters, but on account of a smaller number of observations at high altitudes at the other two stations the records were computed to 4,000 meters only.

TABLE 1.—*Mean free-air winds at Broken Arrow, Okla.,[1] latitude, 36° 2′ N.; longitude, 95° 49′ W.; elevation, 233 meters.*

Altitude (meters).	Spring.		Summer.		Autumn.		Winter.		Annual.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
	°	m/s.		m/s.		m/s.		m/s.		m/s
Surface	S. 19° E.	6.8	S. 16° E.	4.6	S. 19° E.	5.6	S. 63° W.	6.3	S. 7° E.	5.8
250	S. 3° W.	8.5	S. 7° W.	6.3	S. 3° W.	8.1	S. 76° W.	7.9	S. 15° W.	7.7
500	S. 19° W.	9.8	S. 17° W.	6.8	S. 15° W.	9.2	S. 85° W.	9.3	S. 29° W.	8.8
750	S. 36° W.	10.2	S. 22° W.	6.7	S. 27° W.	9.3	S. 87° W.	10.0	S. 41° W.	9.0
1,000	S. 54° W.	10.4	S. 26° W.	6.5	S. 36° W.	9.3	N. 87° W.	10.8	S. 51° W.	9.3
1,500	S. 73° W.	10.8	S. 34° W.	6.2	S. 63° W.	9.2	N. 80° W.	11.8	S. 69° W.	9.5
2,000	S. 87° W.	11.7	S. 51° W.	6.0	S. 78° W.	9.7	N. 78° W.	13.4	S. 82° W.	10.2
2,500	N. 86° W.	13.2	S. 75° W.	6.1	S. 84° W.	10.1	N. 77° W.	14.6	N. 89° W.	11.0
3,000	N. 83° W.	14.7	N. 83° W.	6.5	S. 89° W.	10.6	N. 76° W.	16.5	N. 81° W.	12.1
3,500	N. 80° W.	16.2	N. 67° W.	6.7	N. 89° W.	11.5	N. 78° W.	18.0	N. 79° W.	13.1
4,000	N. 82° W.	17.2	N. 50° W.	7.0	N. 79° W.	12.6	N. 74° W.	19.0	N. 72° W.	14.0
4,500	N. 83° W.	19.1	N. 45° W.	7.6	N. 76° W.	13.5	N. 70° W.	20.8	N. 68° W.	15.2
5,000	N. 75° W.	20.3	N. 44° W.	7.6	N. 71° W.	14.8	N. 65° W.	21.8	N. 62° W.	16.1
6,000	N. 74° W.	22.5	N. 48° W.	9.2	N. 58° W.	17.3	N. 60° W.	24.5	N. 58° W.	18.4

[1] To change meters per second to miles per hour multiply by 2.236932, or 2¼ approximately. Directions are recorded as the point from which the wind comes; e. g., a west wind is one from the west.

TABLE 2.—*Mean free-air winds at Fort Sill, Okla.,[1] latitude, 34° 40′ N.; longitude, 98° 25′ W.; elevation, 355 meters.*

Altitude (meters).	Spring.		Summer.		Autumn.		Winter.		Annual.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
		m/s.		m/s.		m/s.		m/s.		m/s
Surface	S. 1° W.	5.4	S. 19° E.	3.8	S. 26° E.	3.8	N. 66° W.	5.2	S. 9° E.	4.6
250	S. 11° W.	8.2	S. 1° W.	7.0	S. 5° E.	7.6	N. 75° W.	7.4	S. 12° W.	7.6
500	S. 24° W.	9.9	S. 5° W.	8.8	S. 16° W.	9.2	N. 79° W.	9.0	S. 27° W.	9.2
750	S. 36° W.	9.7	S. 12° W.	8.5	S. 19° W.	9.6	N. 86° W.	9.6	S. 34° W.	9.4
1,000	S. 43° W.	9.6	S. 19° W.	7.7	S. 30° W.	9.4	W.	10.3	S. 43° W.	9.3
1,500	S. 58° W.	10.7	S. 28° W.	6.9	S. 62° W.	8.8	N. 86° W.	11.1	S. 57° W.	9.4
2,000	S. 69° W.	12.2	S. 28° W.	6.7	W.	9.0	N. 80° W.	11.8	S. 69° W.	9.9
2,500	S. 77° W.	14.4	S. 49° W.	6.5	N. 88° W.	9.3	N. 84° W.	12.9	S. 81° W.	10.7
3,000	N. 87° W.	15.0	S. 61° W.	6.6	N. 76° W.	10.6	N. 82° W.	14.8	N. 81° W.	11.7
3,500	N. 87° W.	15.8	N. 2° W.	7.7	N. 75° W.	11.1	N. 80° W.	16.2	N. 77° W.	12.7
4,000	N. 78° W.	17.8	N. 36° W.	7.9	N. 74° W.	11.7	N. 76° W.	17.8	N. 70° W.	13.8

[1] To change meters per second to miles per hour multiply by 2.236932, or 2¼ approximately. Directions are recorded as the point from which the wind comes; e. g., a west wind is one from the west.

TABLE 3.—*Mean free-air winds at Fort Omaha, Nebr.,*[1] *latitude, 41° 20′ N.; longitude, 96° 00′ W.; elevation, 350 meters.*

Altitude (meters).	Spring.		Summer.		Autumn.		Winter.		Annual.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
		m/s.		m/s.		m/s.		m/s.		m/s
Surface	E.	5.5	S. 23° E.	3.9	S. 40° W.	5.2	S. 82° W.	5.5	S 14° W.	5.0
250	S. 54° E.	9.0	S. 1° E.	6.9	S. 43° W.	7.7	N. 80° W.	8.7	S. 36° W.	8.0
500	S. 38° E.	9.9	S. 10° W.	7.7	S. 58° W.	9.3	N. 77° W.	10.4	S. 48° W.	9.3
750	S. 43° W.	10.0	S. 22° W.	7.8	S. 70° W.	9.8	N. 87° W.	11.2	S. 60° W.	9.7
1,000	S. 67° W.	10.1	S. 37° W.	8.1	S. 80° W.	10.4	N. 81° W.	11.9	S. 71° W.	10.1
1,500	S. 89° W.	10.4	S. 57° W.	8.8	S. 89° W.	11.4	N. 69° W.	13.5	S. 89° W.	11.0
2,000	N. 85° W.	11.6	S. 80° W.	9.4	N. 84° W.	11.8	N. 65° W.	14.5	N. 85° W.	11.8
2,500	N. 80° W.	13.0	N. 84° W.	10.1	N. 71° W.	14.1	N. 66° W.	15.9	N. 74° W.	13.3
3,000	N. 86° W.	13.7	N. 88° W.	11.1	N. 71° W.	15.1	N. 64° W.	17.3	N. 76° W.	14.3
3,500	N. 79° W.	15.8	N. 79° W.	11.2	N. 72° W.	15.9	N. 62° W.	18.9	N. 71° W.	15.5
4,000	N. 67° W.	16.3	N. 71° W.	11.9	N. 81° W.	16.8	N. 70° W.	20.6	N. 74° W.	16.4

[1] To change meters per second to miles per hour multiply by 2.236932, or 2½ approximately. Directions are recorded as the point from which the wind comes; e. g., a west wind is one from the west.

TABLE 4.—*Number of observations on which are based the mean values given in Tables 1, 2, and 3.*

Altitude.	Broken Arrow, Okla.					Fort Sill, Okla.					Fort Omaha, Nebr.				
	Spring.	Summer.	Autumn.	Winter.	Annual.	Spring.	Summer.	Autumn.	Winter.	Annual.	Spring.	Summer.	Autumn.	Winter.	Annual.
Surface	317	344	297	279	1,237	293	318	241	246	1,098	139	158	132	138	567
250	317	344	291	278	1,230	292	317	241	245	1,095	138	158	130	138	564
500	308	338	279	260	1,185	276	315	230	236	1,057	134	155	128	127	544
750	290	328	263	250	1,131	258	306	210	219	993	124	154	118	107	503
1,000	267	322	259	243	1,091	231	296	198	203	928	114	144	110	106	474
1,500	223	299	239	221	982	189	275	152	179	795	88	115	96	85	384
2,000	188	270	217	192	867	155	228	124	150	657	67	77	72	72	288
2,500	147	232	188	170	737	124	174	94	125	517	45	55	45	55	200
3,000	121	212	168	153	654	99	136	77	100	412	30	45	41	37	153
3,500	91	185	150	132	558	85	120	66	80	351	22	35	31	27	115
4,000	80	159	122	112	473	68	97	58	72	295	15	28	25	18	86
4,500	62	131	106	80	379	----	----	----	----	----	----	----	----	----	----
5,000	52	121	96	69	338	----	----	----	----	----	----	----	----	----	----
6,000	37	104	77	46	264	----	----	----	----	----	----	----	----	----	----

The seasonal means for Broken Arrow are shown graphically in figure 1, and the annual frequency of directions in percentages is shown for various levels in figure 2. The percentage frequencies of a west component at Broken Arrow at the surface, and at 1, 2, 4, and 6 kilometers are 46, 70, 78, 80, and 80, respectively; at the surface, and 1, 2, and 4 kilometers, these are for Fort Sill: 46, 68, 74, and 72, and for Fort Omaha: 53, 74, 86, and 94. A decrease in the preponderance of westerly winds with decreasing latitude is thus to be seen. (Cf. also Table 10, reference **2**.)

Reliability of the data.—Most of the records here used were obtained by the one-theodolite method, the ascensional rate of the balloon being computed by a formula based on the weight and free lift of the balloon. Accuracy of the records therefore depends on whether the balloons rise at the rate computed. It has been shown (**1**) that the error in the rate of ascent under stable conditions of the air is negligible. When convection is active, as on summer afternoons, the error may be large in the lower layers, and it is necessary to use two theodolites to get accurate records. Convection nearly always displaces the balloon upward; downward displacements are usually weak.

Tables 1 to 3 are based on two daily observations taken, whenever weather permitted, at 7 a. m. and 3 p. m. (90 meridian time). These observations occur near the time of the minimum and maximum surface wind, and represent a close approach to the daily mean. During the two-year period 87 per cent of the possible number of observations were taken at Broken Arrow, excluding part of the time when Sunday morning runs were not made. The seasonal distribution is therefore good, although a somewhat higher percentage of observations was made during summer than winter.

The means for Broken Arrow and Fort Sill are very similar and are believed to be essentially accurate for the period covered. There are, no doubt, appreciable errors in some of the individual observations, but they have been

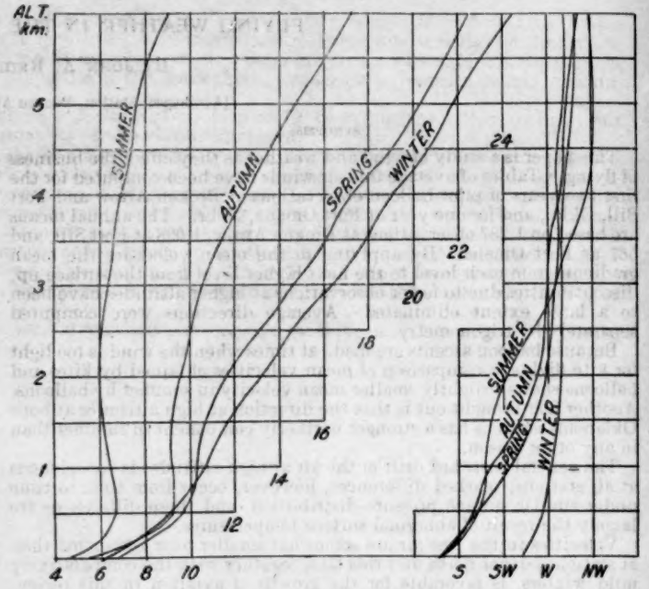

FIG. 1.—Mean seasonal free-air wind velocity (m/s) and direction, at Broken Arrow, Okla.

largely if not entirely eliminated by the large numbers used. The largest source of error—the disturbing effect of convection on the rate of ascent of the balloon on summer afternoons—was largely overcome by using two theodolites.

The question as to whether the two years were normal years and therefore the winds represent normal conditions can be determined only after a longer period of observations is available. It is not probable, however,

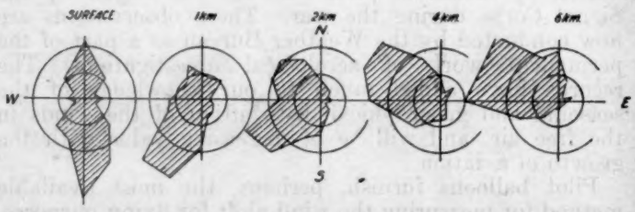

FIG. 2.—Annual mean frequency of direction at Broken Arrow, Okla. Circles represent 5 and 10 per cent, respectively, of the total from any one of the 16 points.

that normal winds will be greatly different from the conditions here depicted. The departure of a short period from normal is evident from the direction in the lower levels in spring at Fort Omaha, where the means are based on one year only. The strong easterly component in the spring of 1919 is also evident at Broken Arrow and Fort Sill, but its effect is obscured at the latter places by another year's record.

A comparison of the published means of wind from kite records at Drexel, Nebr. (**2**), aside from the difference

resulting from geographical location, reveals, as was expected, smaller velocities at all altitudes in summer. This is due in the first place to the fact that part of the time the wind is too light to support a kite; and secondly, kite flights are made in the morning on many days when there is little wind near the ground in the afternoon.[1]

Another difference in the comparison is that although kite records show a southerly component at all altitudes in summer, balloon records show a stronger northerly component over Oklahoma at high altitudes in this season than in any other. The most common summer condition is a moderate south wind in the lower layers, above which is a rather deep layer of light wind, with northwesterly winds at still higher altitudes.

The Southern Plains States lie well to the south of the average storm tracks. Winters are comparatively mild, and a large proportion of the time throughout the year is favorable for aviation. Surface winds blow very steadily from the south during the summer; but during the winter there is nearly a balance between the north and south winds, with the result that winter means at

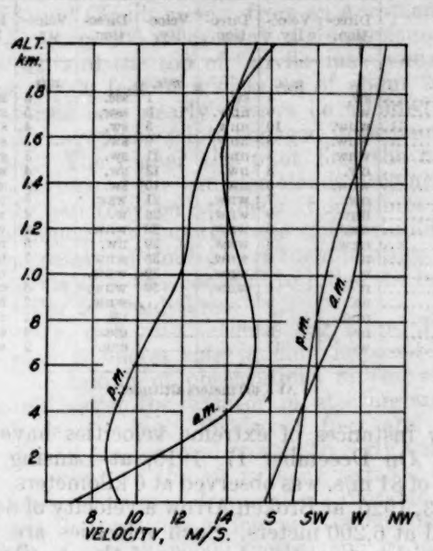

FIG. 3.—Mean 7 a. m. and 3 p. m. wind velocity and direction at Broken Arrow, Okla., for March, 1920.

Broken Arrow show a southerly component and those at Fort Sill a slight northerly component. The depth of the southerly component increases from winter to summer, and velocities decrease at the same time.

A rapid increase in velocity from the ground to approximately 500 meters occurs at all seasons; above this there is little or no increase to 1,500 meters, and there may be a decrease as occurs in all seasons except winter at Fort Sill. Above 1,500 meters there is a nearly constant increase to at least 10 kilometers. The decrease in velocity above 500 meters is sometimes caused by a rapid shift in direction, but occurs also when there is little or no change in direction. It is not the result of convection because it is most marked in the early morning (fig. 3) when vertical currents are at a minimum. No satisfactory explanation of this phenomenon has been found, but it is suggested that surface pressure systems, which exert a shallow influence in this region, may interact with the general circulation to interrupt the normal increase aloft.[2]

Westerly winds, as is generally known, increase with altitude; easterly winds continue light to an indefinite altitude or shift to west. This shift may be a gradual veering through south and southwest, or a sharp line may divide the lower easterly and the overrunning westerly winds. A detailed discussion of the turning of the winds with altitude will be found in MONTHLY WEATHER REVIEW, January, 1918 (3). The deductions there made concerning the effect of passing HIGHS and LOWS are equally applicable for this region.

CHANGES—ANNUAL, DIURNAL, AND IRREGULAR.

The march of the wind has three characteristics—annual, diurnal, and irregular. The annual march is shown in the tables, and in figure 1. Highest velocities occur in winter, except that in the first kilometer they may occur in spring; lowest velocities at all altitudes occur in summer.

The diurnal change is shown in figure 3, which is a graph of the a. m. and p. m. means at Broken Arrow during March, 1920, a period of unusally strong winds. During the early morning an observation of the surface wind gives little indication of the wind aloft. Figure 4, a horizontal projection of the balloon's path on the morning of September 18, 1920, during anticyclonic weather, gives an idea of the infinite variety of changes that occur in the free air from day to day. In the morning the velocity may increase from light on the ground to gale force within a few hundred meters. On the morning of March 27, 1920, the wind increased from 8.5 m/s at the surface to 30 m/s at 500 meters and 34 m/s at 900 meters. During the day convection and turbulence tend to remove such irregularities and to bring about nearly the same direction and velocity throughout the first kilometer, as illustrated in figure 3.

Irregular changes in velocity at any level are the result of changes in the horizontal pressure gradient at that level. Winds near the ground result from passing HIGHS and LOWS, but at moderate altitudes the free-air winds are determined primarily by the surface temperatures, and the cause of abnormal winds aloft is generally to be found in an abnormal surface temperature distribution, in its effect on the free-air pressure distribution.

ABNORMAL WINDS ALOFT.

Present-day aviation is most concerned with the winds of the first 2 kilometers, but in view of the discussion among fliers of the possibility of flying at enormous speeds by taking advantage of the winds at high altitudes a brief summary of these winds seems desirable. During the two years' record at Broken Arrow 71 balloons have been observed to the 10-kilometer level (32,808 feet), and the velocities found there are certainly ample to carry the flier well on his way provided he can maintain the altitude. By applying the gradients from 6 to 10 kilometers to the velocities at 6 kilometers, the velocities indicated for 10 kilometers are: Spring, 38 m/s.; summer, 17 m/s.; autumn, 28 m/s.; and winter, 47 m/s. The number of winter observations is too small to afford entirely reliable means, but the annual mean, 33 m/s.,

[1] Values for the other three seasons and the means for the year agree closely at Drexel and at Fort Omaha, those at the latter averaging about 1 m. p. s. lower than those at Drexel. (See Table 6, reference 3, and Table 3, this paper.) The two stations are about 30 kilometers apart.—W. R. G.

[2] Thus in the lower layers easterly winds are nearly as frequent as westerly winds (see fig. 2). The latter ordinarily increase in speed with altitude rather gradually during the summer, but the former almost invariably die out completely shortly after the 500-meter level is reached. The average of the *sharp* decrease in velocity of easterly winds and the *moderate* increase in velocity of westerly winds results in the *slight* decrease noted in the mean values for the summer season, Tables 1 to 3.—W. R. G.

agrees quite well with the determination of cirrus cloud movements at Blue Hill and Washington (4). The percentage of westerly winds has decreased somewhat, but this is more apparent than real, because the balloon rising in a west wind generally passes beyond the range of visibility before reaching this altitude.

But even the strong westerlies of winter are interrupted at intervals by light winds which at times have an easterly direction so that the aviator who is equipped for high-altitude flying and desires to use the strong westerlies is still dependent on the meteorologist for the prediction of their occurrence.

Examples of abnormal winter winds are found in Table 5. High-altitude easterly winds at this season, as occurred on the morning of January 29, 1919 (columns 1 and 2), are unusual. These easterly winds continued with decreasing altitude through the afternoon and during the next day, gradually giving way to the prevailing west wind. On the morning of December 14, 1919 (columns 3 and 4), the wind was abnormal in that it was unusually high. Starting with almost a calm at the surface the

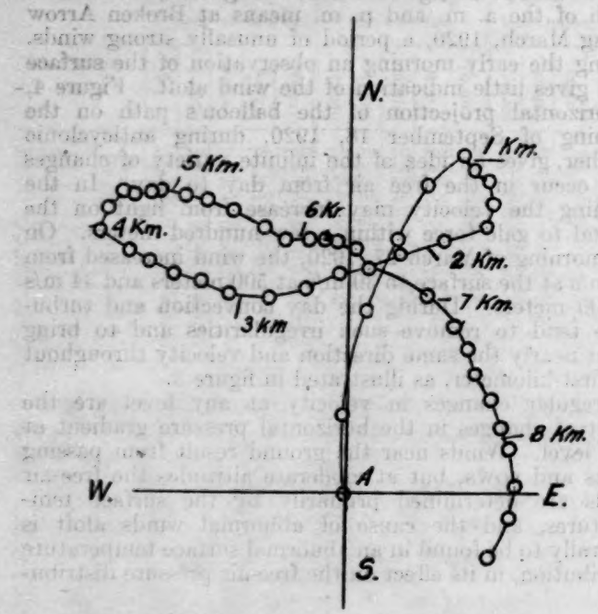

FIG. 4.—Horizontal projection of balloon's path, Broken Arrow, Okla., 7:55 a. m., Sept. 18, 1920. Small circles mark consecutive minutes. A, observation point. Scale, 1 centimeter, 400 meters.

wind increased steadily to a velocity of 50 m/s. (112 m. p. h.) at 5,400 meters. These two observations were made under similar surface pressure distribution, i. e., there was a ridge of high pressure over the West and South, with low pressure over the North and East. It is therefore evident, as stated by Mr. Gregg, that "Surface pressure systems have little influence in this respect except in so far as they produce modifications in the surface temperature distribution. * * * The relation between the surface horizontal temperature distribution, in its effect on free-air pressure gradients, and the winds in the middle and upper portions of the troposphere," is further brought out.

The temperature distribution on these two dates was entirely dissimilar. On December 14, 1919, there was a very steep south-to-north temperature gradient over the eastern part of the country. This resulted in free-air pressure gradients toward the north, which became steeper with increasing altitude, and caused winds of unusual velocity in the middle troposphere. On January 29, 1919, the normal poleward temperature gradients were reversed, with high temperatures over the Dakotas and low temperatures in the Southwest. As explained in the MONTHLY WEATHER REVIEW for a similar occurrence in January, 1920 (5), this caused an elevation of the isobaric surfaces in the North and a depression in the South and Southwest, and resulted in north-to-south pressure gradients and resulting easterly winds at high altitudes over the Plains States. The last four columns of Table 5 show the deep easterly winds over Oklahoma on January 29, 1920; an account of the same phenomenon as observed at Texas stations has been referred to (5).

TABLE 5.—*Abnormal winter winds at high altitudes over Oklahoma.*

Altitude.	Broken Arrow.						Fort Sill.	
	8 a. m., Jan. 29, 1919.		8 a. m., Dec. 14, 1919.		3 p. m., Jan. 29, 1920.		3 p. m., Jan. 29, 1920.	
	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.	Direction.	Velocity.
Meters.		*m/s.*		*m/s.*		*m/s.*		*m/s.*
Surface	sw.	4	sw.	1	sse.	5	ssw.	3
250	w.	9	nnw.	3	ssw.	5	sw.	4
500	wnw.	10	nnw.	5	sw.	4	sw.	4
750	wnw.	8	nnw.	9	sw.	4	sw.	5
1,000	wnw.	7	nnw.	11	sw.	3	sw.	5
1,500	nw.	8	nw.	13	sw.	4	ssw.	5
2,000	wnw.	6	nw.	15	sw.	7	ssw.	4
2,500	nw.	7	wnw.	21	wsw.	5	sw.	4
3,000	nnw.	9	wnw.	26	w.	4	wsw.	3
3,500	nw.	8	wnw.	29	wnw.	4	w.	3
4,000	nnw.	8	wnw.	29	nw.	5	nw.	2
4,500	n.	8	wnw.	35	wnw.	7	nnw.	3
5,000	n.	10	wnw.	39	wnw.	7	n.	2
6,000	n.	6	wnw.	[1]50	wnw.	5	ene.	3
7,000	ne.	9	.....	.....	wnw.	2	e.	5
8,000	nne.	2	.....	.....	ne.	2	e.	10
9,000	ne.	3	.....	.....	ese.	4	ene.	7
10,000	w.	17	.....	.....	ene.	2	ese.	7

[1] At 5,400 meters altitude.

A few instances of extreme velocities have been recorded. On December 17, 1919, at Lansing, Mich., a velocity of 81 m/s. was observed at 6 kilometers. (6) On March 13, 1920, at Broken Arrow a velocity of 84 m/s. was observed at 6,200 meters. Such velocities are to be accepted with reservation because of the possibility of an error due to a leaky balloon, but the similarity of the surface temperature distribution and the velocities observed tends to prove the essential accuracy of these two observations. They are most unusual and occur only in the winter half-year when the pole-ward temperature gradients greatly exceed the normal. On these two dates there was a temperature difference of 56° C. between southern Florida and the northern Lake region.

CONDITIONS UNFAVORABLE FOR FLYING.

High winds.—Surface winds in this region are seldom strong enough to prevent an experienced aviator from taking off or landing with safety, but winds of sufficient force to be a serious obstacle to economical flying into a head wind sometimes persist for one or two days at a time in winter and early spring. At this season the highest surface velocities generally occur from noon to 2 p. m. These winter winds, because of wide distribution and persistence, can be determined and their effect on the course of an airplane can be foretold with reasonable accuracy.

In summer, on the other hand, such winds seldom occur, but the wind feature of most danger to aviators is the squall winds that accompany thunderstorms.

These winds sometimes attain a velocity of 30 m/s. for a short time, and are most frequent from 3 p. m. to 5 p. m. Forecasts of squall winds and thunderstorms, on account of their short duration and the limited area covered, can not well be made on the Weather Bureau report, except to state that conditions are favorable for their occurrence. They usually occur in the southern quadrant of a LOW or near the wind shift line of a V-shaped depression, and move in an easterly direction over a path from a few to 500 kilometers or more, advancing at a rate of 50 to 60 kilometers per hour.

Aviators should study the structure of thunderstorms, and the direction of the attendant winds in relation to the path of the storm, bearing in mind that with the onset of the squall the surface wind usually veers from a southerly to a northwesterly direction. Dr. Brooks has pointed out the danger of attempting to fly through a thunderstorm due to lightning and the violent turbulence of the air. (7) As a rule the aviator should be able to see the approaching storm in time to make a safe landing before the arrival of the violent squall wind. Capt. C. K. M. Douglas (8) in "Clouds as seen from an Aeroplane," says: "A thunderstorm 100 miles away is a conspicuous object from the air, and the top of 'anvils' may sometimes be seen from 10,000 feet at a distance of about 200 miles. Thunderstorms can nearly always be avoided without difficulty by aeroplane pilots engaged in ordinary peace-time flying. The higher the pilot flies the more conspicuous the tops of the thunder clouds become, and the more easily can they be avoided. Sometimes there are extensive clouds at about the base of the thunder clouds and it is necessary to climb above them in order to see the thunderstorms at a distance, and to judge the best course to fly in order to avoid them."

Fog, clouds, and rain.—Dense fog stops flying, not only because it makes safe landing impossible, but it prevents the taking of observations of the wind aloft which would assist the aviator in steering an accurate course above the fog. Persistent fogs are, however, infrequent, and are confined mostly to early winter when the vapor content of the air is being reduced by falling temperatures. The most frequent unfavorable condition for flying is the presence of low stratus clouds, often at an altitude of less than 500 meters, and in many cases accompanied by precipitation. Flying beneath such clouds is inadvisable because of the danger of having to make a forced landing within a limited area and the chance for accident because of surface obstructions. Furthermore, intermittent precipitation when the temperature is slightly below freezing will soon cause an accumulation of ice and make a forced landing unavoidable. For a discussion of the advantages of flying above and below the clouds reference should be made to "Over-Cloud Flying and Commercial Aeronautics," Aviation, June 15, 1920.[3]

A record of the number of times that balloon runs were not made because of adverse weather gives a rough estimate of the frequency of these conditions. Table 6 gives the number of winter and summer days during the two-year period at Broken Arrow when one or both runs were not made. From this table it is seen that there are approximately 14 per cent of winter days and 7 per cent of summer days that are somewhat unfavorable for flying; and 10 per cent of winter days and 2 per cent of summer days that are decidedly unfavorable.

[3] Abstract in MO. WEATHER REV., September, 1920, pp. 528-529.

TABLE 6.—*Number of days balloon runs were not made because of adverse weather (2-year record).*

Cause.	Winter, October–March.		Summer, April–September.	
	Observations missed.		Observations missed.	
	One.	Two.	One.	Two.
Fog	3	8	1	0
Rain or snow	22	16	9	5
Low clouds	25	13	15	3
Total	50	37	25	8

Best altitude for flying.—The aviator who finds himself without a daily wind report will find the tables of seasonal averages of value in selecting the best altitude for flying. In summer the wind is usually unimportant but in winter, because of the large percentage of strong westerlies aloft, the aviator will find it best to fly high, above 1,000 meters, on an eastward trip and low on a westward one. For the same reason cross winds will be encountered in north and south flying and low altitude is again advisable. However, if strong head winds are found while flying north or south the following condition is likely to occur: A rapid increase in velocity from the ground to an altitude of 500 to 1,000 meters, with a decrease, sometimes very rapid, at higher altitudes; and it will be best to try to find a region of lighter wind at elevation of 1,500 meters or more. This is an early morning condition and leads us to the next paragraph.

Best time of day for flying.—Flying in winter may often be done best near midday or in the afternoon because of the presence at times of morning fogs or low stratus clouds which are dissipated by the rising sun. Also, at ordinary flying altitudes wind velocities are less than in the early morning (fig. 3). In summer morning hours are best because the wind is steady, visibility is good, and local storms are not likely to occur; while in the afternoon turbulence sets in (bumpiness in flying) and this process may continue until thunderstorms are formed. Turbulence is caused by rough topography, buildings, the meeting or flowing past each other of air currents of different direction and density, and causes many of the peculiar phenomena of the air that the aviator has to face. These are dealt with fully by Prof. Humphreys, in "Physics of the Air," Chapter XI, pages 214–225. In a level country the principal cause of turbulence is daytime convection or the rising of heated air from the surface to a height of a kilometer or more by a process analogous to the rising of gas bubbles in boiling water. When a rising mass becomes large enough its upper limit is marked by a cumulus cloud. The cloud may soon dissipate or it may grow to large size, depending on the temperature and moisture of the rising air. Cumulo-nimbus clouds and thunderstorms are the culmination of this process.

Figure 5 shows to what extent the air may be disturbed by convection on summer afternoons, even though there is no approach to thunderstorm conditions. On June 25, 1920, two ascents were made at short intervals, and the position of the balloon was computed at the end of each minute by the two-theodolite method. Both balloons had nearly the same ascensional rate by formula, that of the first being 161 m/m and of the second 160 m/m. The

first balloon, released at 2:46 p. m., rose at an average rate of 171 m/m, having been affected only slightly by convection. The second was released at 3:12 p. m., directly underneath a rather large cumulus cloud. A convectional gust caught the balloon as it left the ground, and from the end of the first to the third minute the ascensional rate was 422 m/m, or 264 per cent of the rate by formula. This gives an upward movement of the air around the balloon at a rate of 4.4 m/s. Such vertical gusts, usually much less marked, are the cause of "bumps" experienced on warm afternoons. If such a sustaining force were suddenly removed from an airplane the sensation would be that of a "hole in the air."

When convection is evident the air is also gusty, i. e., there is a rapid fluctuation in the horizontal or true wind velocity. In figure 5 it is seen that the velocity just off the ground drops from nearly 10 m/s. in the first ascent to less than 6 m/s. in the second.

Acknowledgment is due to Mr. W. R. Gregg for the use of the unpublished records of the Aerological Division on which the tables of average winds are based, and for valued suggestions and assistance rendered throughout the preparation of this paper; also to the men of Broken Arrow station for the cooperation which enabled me to compute the data under conditions of very limited personnel.

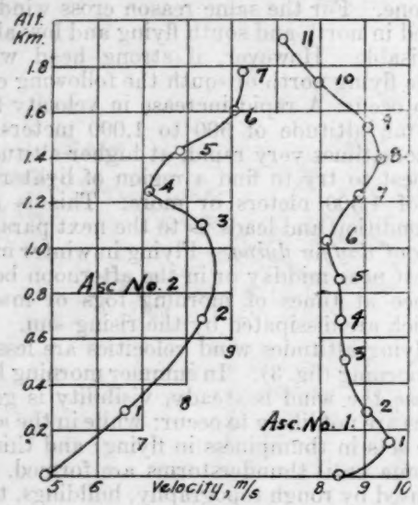

FIG. 5.—Time, altitude, velocity graph of pilot-balloon ascensions at Broken Arrow Okla., June 25, 1920. No. 1 at 2:46 p. m. No. 2 at 3:12 p. m.

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SURFACE WINDS AND LOWER CLOUDS.

By F. E. HARTWELL, Meteorologist.

[Weather Bureau Office, Burlington, Vt., December, 1920.]

There is an unfortunate tendency among weather observers to record the lower clouds from the same direction as the surface wind. Indeed, in the writer's first lesson in taking a meteorological observation, when it came to the clouds, the entry was dictated to him: "3 stratus, SW., like the wind, *of course*."[1]

Shortly thereafter, an intimate association with the West Indian hurricane in its own habitat indicated to him the importance of cloud drift in determination of direction of storm centers from the station, so that he has always been particularly careful to enter cloud directions from a careful sight, without reference to surface currents.

At the end of a year's work here in Burlington with pilot balloons, an examination of the record of flights made shows the fallacy of an assumption that the lower clouds, "of course," drift with the surface wind.

During the year, the actual direction of lower clouds was determined by means of balloon flights 186 times. Of these 186 only 28, or 15 per cent, were recorded the same direction as the surface wind. However, the directions in this work are recorded to sixteen points, while in ordinary meteorological observations they are recorded to only eight points. Therefore, those varying one-sixteenth either side of the surface direction must be included in determining the possible error. These bring the percentage of lower clouds with surface winds up to 38, less than four out of ten, quite a considerable error. Following the circle around, there were about one in four at a divergence of 45° from the surface wind, nearly one in three almost at right angles, 2 per cent at 135°, and 4 per cent nearly opposite.

This computation takes into consideration all directions. A segregation of the different directions is not particularly pertinent to the conclusion sought, but the deviation of the drift of lower clouds from surface wind direction varied somewhat with the surface direction, being greatest near east, and least at north. This variation would probably differ at different latitudes to such an extent that a detailed statement of it would be valueless.

The foregoing statements refer to occasions when a lower cloud direction was actually determined. The record was further examined with reference to the 500 and 1,000 meter levels, which include most lower clouds, and these results, with the foregoing, are included in the following table:

Percentage of direction of lower clouds and of drift at selected levels compared with surface wind direction.

Deviation from surface direction (degrees of azimuth).	Lower clouds (186 observations).	500-meter level (546 observations).	1,000-meter level (495 observations).
	Per cent.	*Per cent.*	*Per cent.*
0 (surface direction)	15	20	14
22½	23	37	24
45	26	20	22
67½	17	9	16
90	9	7	11
112½	4	2	5
135	2	2	3
157½	3	2	3
180	1	1	2

[1] It is hoped that such an instruction would be exceptional among officials in charge of Weather Bureau stations at present. We know that the observers at the majority of stations take pains to observe the direction of motion of the lower clouds.—EDITOR.

Reducing these values to the eight-point basis gives the following results:

Percentage of direction of lower clouds and of drift at selected levels compared with surface winds, deviation reduced to 8 points of the compass.

Deviation from surface direction.	Lower clouds.	500-meter level.	1,000-meter level.
	Per cent.	*Per cent.*	*Per cent.*
Practically with surface wind	38	57	38
Deviation of 45°	26	20	22
Practically at right angles	30	18	32
Deviation of 135°	2	2	3
Practically opposite	4	3	5

The observed lower clouds were taken by their form, and without regard to altitude, and varied from more than 1,000 meters to less than 500 meters above the earth's surface. It will be seen that the deviation increases decidedly with altitude, so that it can not be too strongly impressed upon observers begining Weather Bureau or other meteorological work that direction of lower clouds should not be assumed to be the same as the direction of the surface wind.

THE HIGHEST AERIAL SOUNDING.

In the *Meteorological Magazine* for November, 1920, No. 658, vol. **55**, Mr. F. J. W. Whipple calls attention to the fact that the sounding-balloon record made at Pavia on December 7, 1911, heretofore accepted by many as the highest yet made, is in reality very questionable. Basing his figures upon the data given in a paper by Prof. Pericle Gamba, he finds that if the balloon *did* reach the great height claimed, viz, 35,030 meters, its mean rate of ascent during the latter part of its journey—from 27 to 35 kilometers altitude—was somewhat greater than 900 meters per minute, whereas its initial rate was about 235. At the highest point reached the indicated pressure was 4 mm. If this is correct, it means that the balloon's volume was nearly 200 times that at starting and the diameter 6 times. Mr. Whipple believes that the barograph was not working properly and, assuming a constant ascensional rate, finds that the altitude reached was about 19 kilometers. Although the original height given, 35,030 meters, does appear very questionable, it is difficult to accept this recomputed value, since it is based entirely upon an assumed constant ascensional rate of the balloon. It is true that small pilot balloons rise at very nearly a constant rate, but it is not true that the larger balloons, from which instruments are suspended, do so. The sounding-balloon ascensions made in this country show, in practically all cases, an increasing rate of ascent with increasing altitude. In 20 ascensions at Fort Omaha, Nebr., and Huron, S. Dak., the mean rate increased from 180 meters per minute near the surface to 300 at 15 kilometers. (See BULLETIN MOUNT WEATHER OBSERVATORY, Washington, 1911, **4**: 187.) In 7 ascensions at Avalon, Calif., the mean rate increased from 185 meters per minute near the surface to 295 at 18 kilometers. (See MONTHLY WEATHER REVIEW, Washington, 1914, **42**: 411.) Objection may be raised to these records as reliable evidence, since the heights were themselves computed from the pressure records. This is true in the cases cited, but in 1914 several balloons were followed by 2 theodolites at Fort Omaha, Nebr. (See MONTHLY WEATHER REVIEW, Washington, 1916, **44**: 247–264.) A base line 5,088 meters in length was used. The results indicated close agreement between altitudes determined from triangulation and those from the barograph. Using only those ascensions in which the balloons were followed by 2 theodolites, we find that the mean rate of ascent increased from 150 meters per minute near the surface to 240 at 17 kilometers. The increase is fairly constant at all altitudes below 15 to 18 kilometers and is practically the same in the individual ascensions. It seems certain, therefore, that the height reached by the Pavia balloon was considerably greater than that computed on the basis of a constant rate of ascent. It seems also quite certain that that height was considerably less than 35 kilometers.

Mr. Whipple inquires what sounding is the highest on record, if the Pavia record is to be deprived of that distinction. So far as known, the next highest observation published is that made at Avalon, Calif., on July 30, 1913. As computed from the barograph trace, an altitude of 32,640 meters was reached. The pressure was 7.4 millimeters. The rate of ascent was about 100 meters per minute near the surface, 275 at 16 kilometers, and 520 at the highest altitudes.

The next highest record in this country was that obtained at Fort Omaha, Nebr., July 9, 1914. Unfortunately, the meteorograph clock stopped when an altitude of 17,560 meters had been reached. This altitude, by the way, was determined by triangulation as well as from the pressure trace. The clock started again when the balloon burst, and fortunately the time of bursting was ascertained, the balloon still being followed by one of the theodolites. Thus it is possible to determine the mean rate of ascent at the highest altitudes, if we can assume that the indicated pressure at the time of bursting of the balloon was correct. That pressure was 8.6 millimeters, giving an altitude of 31,600 meters. The rate of ascent was 115 meters per minute near the surface, 230 at 15 to 17 kilometers, and 395 at the highest altitudes.

One other sounding above 30 kilometers was made on September 1, 1910, at Huron, S. Dak. The indicated pressure was 9.8 millimeters, and the computed altitude, 30,490 meters. The rate of ascent was 150 meters per minute near the surface, 330 at 15 to 18 kilometers altitude, and 367 at the highest levels.—*W. R. Gregg.*

LOCAL PECULIARITIES OF WIND VELOCITY AND MOVEMENT ATLANTIC SEABOARD—EASTPORT, ME., TO JACKSONVILLE, FLA.

By SPENCER LEE TROTTER.

[Philadelphia, Pa., June 4, 1920.]

INTRODUCTION.

A study of the conditions of wind velocity and movement along the Atlantic coast of the United States brings to light a number of interesting local peculiarities at the 14 coastal stations selected. Figures for velocity and movement covering a period of five years (1915 to 1919) show such marked contrasts for these stations as to raise the question in the mind of the student as to the reason for their existence. The outstanding features are: First, the difference in velocity and movement between Nantucket and Block Island; second, the marked difference between Sandy Hook and Atlantic City; and third, the increase of wind movement and velocity southward to Hatteras, the decided decrease at Wilmington, N. C., and the corresponding increase again southward to Jacksonville, Fla. At first thought it would be natural to suppose that differences in exposure of the various anemometers would be in a large measure resp nsible, and exposure undoubtedly has some effect on the velocity and movement of the wind at certain stations, especially as regards winds from certain directions.

It is my aim only to point out the conditions as they exist, with the aid of the tables and chart, and to suggest certain causes that may have a deciding influence, the principle cause being the contour of the coast, and topography at various stations of such a character as to affect the movement of surface winds. For this reason, purely ocean data have not been used in this article, as it has to do only with the effect that land may have on coastal winds.

WIND MOVEMENT AT VARIOUS STATIONS.

Eastport, Me.—The first station to be considered is Eastport, Me., situated on an island in the southwest portion of Passamaquoddy Bay, with a narrow, open exposure to the northeast between two Canadian islands, and a fairly open exposure to the west, across a bay between it and the mainland. It gives a total five-year movement of 477,485 miles and a monthly mean of 7,951 miles, with the prevailing wind from the S.; the wind prevailing in that direction, 29 out of 60 months. High velocities, on the other hand, are almost invariably registered from the E. and NE., with a mean maximum velocity of 49 miles per hour from the E. and 46 miles per hour from the NE., as shown in Table 3. "Frequency by Direction" part of the same table, also shows values from the E. and NE. far in excess of any other direction. The prevailing S. wind is due probably to the passage of the great number of LOWS eastward out the St. Lawrence Valley, while the high velocities can be traced to three causes, namely, good exposure of the anemometer to the E. and S.; track of LOWS that move NE. up the coast or east across the Maritime Provinces and largely dominate high-wind velocities in this locality; and the narrow, open exposure to the NE., as before mentioned.

Portland, Me.—At Portland, Me., situated on the SW. side of Casco Bay, with a fairly open exposure to the E. and NE., we find a decided decrease in the total wind movement, in the number of winds, 50 miles per hour and over, and in the mean maximum for the five-year period; this last, 36 miles per hour against 44 at Eastport. Though the exposure of the Portland anemometer is good and 32 feet higher than that of Eastport, it must be borne in mind that the former is a city exposure and must necessarily be affected to some extent by the buildings surrounding it. As in the case of Eastport the prevailing wind direction is S., but the greatest value for the relative frequency is NW., being 18, with 6 for SE. as second. How great an effect the surroundings have upon the local conditions is hard to tell, but the fact that the maximum velocities are mostly registered from the NW., where comparatively high ground exists may be one influence responsible for the decrease in velocity.

Boston, Mass.—In this connection it is interesting to note that Boston, with a poor exposure, shows a greater total movement and monthly mean than does Portland, though the mean maximum for the former station is 1 mile per hour lower. We again have to take into consideration the question of surroundings, and no fair estimate can be gained of the real conditions of wind existing at this point, but at the same time it is well to note the difference between Boston and Portland in connection with the land topography to the SW., W., and NW., and the possible effect that the same may have upon the wind at these two points. SW., W., and NW. of Portland the land is comparatively high, while at Boston it is only moderately hilly and would tend naturally to give greater movement. In the case of maximum velocities, the Boston exposure is without doubt the principal reason for the relatively low readings, and it is well known that velocities at Boston Light and points beyond the harbor greatly exceed those of the city.

Nantucket, Block Island, and Sandy Hook.—At the three stations of Nantucket, Block Island, and Sandy Hook, we are able to gain a better idea of the true conditions of coastal wind velocity and movement, and find differences that again bring up the question of topography and its influence on surface winds. At Nantucket we have a total five-year movement of 702,355 miles and a monthly mean of 11,706 miles; prevailing wind from the SW., 40 winds 50 miles per hour or over, and a mean maximum of 50 miles per hour, with a relative frequency value of 25 from the NE. At Block Island we have a total movement of 779,878 miles and a monthly mean of 12,988 miles, prevailing wind from the SW., 109 winds 50 miles per hour or over, with a relative frequency value of 30 from the NW. It can be seen from the above that there is a decided increase in both velocity and movement at Block Island, and though, as a whole, the exposure of the Block Island station is better than that of Nantucket, it does not seem that this is great enough to be responsible for the whole difference, especially as regards the number of winds 50 miles per hour or over; Block Island registering 69 more than Nantucket.

The reason for this difference may lie in the fact that Block Island is situated within a short distance of the mouth of Long Island Sound and the possibility of surface winds becoming contracted or funneled by two masses of land flanking a body of water such as the Sound. That surface winds tend to contract and become stronger, seems to be borne out in the case of river valleys, and it is reasonable to suppose that the conditions at Block Island are governed by the same cause.

At Sandy Hook there is a decrease in movement, but little or no decrease in velocity, a prevailing NW. wind,

and a relative frequency value of 26 from the NW. The contour and topography of the coast in this locality is such as would tend to funnel winds, as in the case of Long Island Sound, and it certainly seems that there is some definite cause for high readings here, when we pass south to the Atlantic City station, less than a hundred miles distant, and find a decrease in total movement of over 300,000 miles, and in monthly mean of over 5,000 miles, with no winds of 50 miles per hour or over during the five-year period, compared with 106 at Sandy Hook. At no two other stations on the coast is the contrast so striking, and it seems even more certain in the cases of Atlantic City and Sandy Hook, that exposure is not responsible. The land to the west of Atlantic City is practically flat, which, with the presence of the Atlantic Highlands to the west of Sandy Hook, would seem to strengthen the theory of higher velocity and movement by contraction or funneling. At any rate, there is no apparent natural cause in the locality of Atlantic City that would tend to decrease the velocity and movement of the wind, and the nearness of it to Sandy Hook would preclude the possibility of the movement of LOWS having anything to do with the decrease.

Cape May, N. J.—A short distance to the south, at Cape May, there is a slight increase in velocity and movement, which may be attributed to the fact that it is practically surrounded on three sides by water. Five-year statistics for the Delaware Breakwater (12 miles to the south) were not available at the time this article was written, but such figures as have been noted for a shorter period, point to the fact that there is a decided increase in both velocity and movement at this station. The fact that it has an open northwest exposure may be largely responsible for this, however.

Cape Henry, Va.—At Cape Henry, Va., there is a material increase in velocity and movement, the station registering a total movement of 598,800 miles, a monthly mean of 9,980 miles, and a mean maximum of 50 miles per hour, while the maximum relative frequency value is 25 north. The location of the Cape Henry atation as regards the surrounding bodies of land and water is much the same as that of the Delaware Breakwater, and the comparatively high figures might be attributed to the same causes that control the conditions there. There is, however, an increase in movement of a marked character at the Hatteras station, though a slight decrease in velocity, and even taking into consideration the fact that the Hatteras station has a sea exposure on practically all sides, it hardly seems that this, combined with the location of the Cape Henry station would form a deciding factor in the great differences of velocity and movement between the Hatteras-Cape Henry and Cape May-Atlantic City stations.

Wilmington, N. C.—At Wilmington, N. C., there is a marked decrease again, with readings that are approximately the same as those of Atlantic City. It is interesting to note in connection with this, that the trend of the coast at these two stations is practically the same, or in other words, NE. to SW.

Charleston, Savannah, and Jacksonville.—Again we might attribute the decrease at Wilmington to the fact that the station is some miles from the sea, were it not for the increase at Savannah and a further increase at Jacksonville, both stations some 20 miles inland. Charleston shows higher readings than Wilmington also, though the proximity of the former station to the sea would not make a material increase unnatural. Velocity readings, however, for both Savannah and Jacksonville are higher than those for Charleston, with Savannah and Jacksonville showing mean maximums of 41 and 44 miles per hour, respectively, and Charleston only 37 miles per hour. As regards winds, 50 miles per hour or over, Savannah and Jacksonville also show a very marked contrast with Charleston; the first two stations with 15 and 23, respectively, and the last-named station with 4.

Figure 1 shows the relative wind passage at the various stations with respect to the contour of the coast. More complete data are given in the tables.

A possible reason for the increase of movement and velocity at certain stations north of Hatteras has been given, but this does not seem to explain the decrease at Wilmington and the succeeding increase at Charleston,

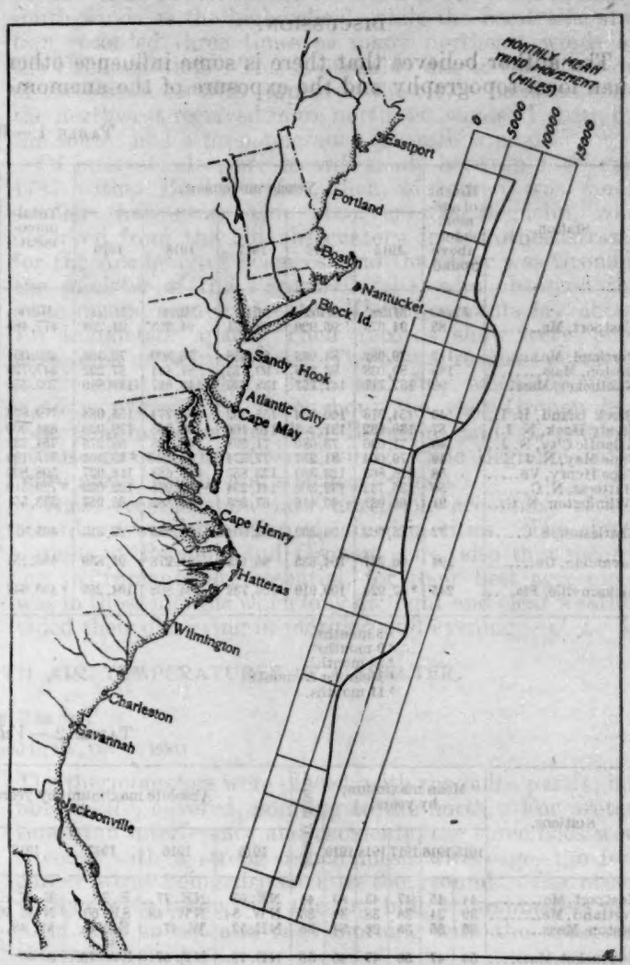

FIG. 1.—Monthly mean wind movement at Atlantic Coast stations.

Savannah, and Jacksonville; differences too marked and general to be governed solely by location. How much influence the trend of the coast has, if any, is a matter not easy to determine with only statistics for widely separated points, where several foreign elements tend to detract from fair readings, but the charts certainly seem to show that there is some definite connection between coastal contour and wind, with the possible effect of topography in certain local areas such as Sandy Hook, taken into consideration.

CONCLUSION.

In conclusion, it may be said that it would be almost worth while to obtain as nearly free readings along the

coast as possible, at various points and in the course of a number of years compare the results obtained. From these, some definite conclusions might be arrived at that would prove, at least, interesting, if not valuable. Ocean data are valuable only so far as they have to do with the ocean, but the influences that govern the conditions there are certainly not the same as those that exist within a short distance of the coast, where hills, river mouths, bays, islands and sounds each become influences of their own on velocity and movement of surface winds, and must go as a whole to form a governing factor in the general movement of winds from various directions. How great this factor is, we have yet to learn.

DISCUSSION.

The author believes that there is some influence other than local topography and the exposure of the anemometer responsible for the variation in wind velocity at certain points along the Atlantic coast. Personally, I think the high winds at Sandy Hook as compared with Atlantic City on the south coast are due almost wholly to the open water surface to the northwest of Sandy Hook. For a similar reason the strong winds at Cape Hatteras as compared with Wilmington, N. C., may be explained. The reason for higher winds at Block Island than Nantucket is not so apparent. I should expect that with northeast winds the velocities would be very nearly the same since the free-water surface in that direction is very nearly the same. With northwest winds, however, Nantucket is blanketed more or less by Marthas Vineyard which lies directly to the northwest of Nantucket.—*A. J. Henry.*

TABLE 1.—*Wind movement.*

Station.	Height of anemometer above ground.	Yearly movement.					Total movement.	Monthly mean.	Number of months by prevailing direction.								Prevailing direction.	Anemometer exposure.
		1915	1916	1917	1918	1919			N.	NE.	E.	SE.	S.	SW.	W.	NW.		
	Feet.	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*										
Eastport, Me.	85	94,673	95,920	98,371	94,253	94,268	477,485	7,951	1	1	0	0	29	1	12	16	s.	Good E. to S.; fair NW.-N.
Portland, Me.	117	79,982	84,963	81,438	76,300	79,366	402,094	6,702	9	1	3	0	21	6	3	17	s.	Good.
Boston, Mass.	188	89,038	93,298	90,723	87,444	87,222	447,725	7,454	0	0	6	0	0	23	19	12	sw.	Poor.
Nantucket, Mass.	90	137,711	141,757	138,430	144,617	139,840	702,355	11,706	2	8	0	0	0	32	3	15	sw.	Good E. to NE.; fair W. to S.
Block Island, R. I.	46	154,313	160,504	156,203	153,774	155,084	779,878	12,998	1	5	0	1	0	26	5	22	sw.	Good.
Sandy Hook, N. J.	57	136,832	131,208	140,166	136,755	139,039	684,000	11,400	0	4	0	1	13	5	10	27	nw.	Do.
Atlantic City, N. J.	48	71,696	73,680	71,598	68,988	68,275	354,237	5,904	1	2	0	0	7	22	0	28	nw.	Fair.
Cape May, N. J.	49	79,054	81,237	77,574	[1] 53,780	[2] 55,464	[3] 347,109	[4] 6,549	5	1	3	2	20	2	1	19	s.[5]	Do.
Cape Henry, Va.	58	116,863	123,369	123,353	116,688	118,027	598,800	9,980	7	13	0	2	8	29	1	0	sw.	Good NE.; fair W.
Hatteras, N. C.	50	126,732	132,306	141,294	[5] 106,955	122,023	[6] 729,310	[7] 12,361	13	17	0	0	1	27	1	1	sw.	
Wilmington, N. C.	91	65,931	69,418	67,363	66,882	63,957	333,551	5,557	91	13	1	0	1	26	10	0	sw.	Good NE.; fair W. to S.
Charleston, S. C.	92	88,662	96,303	92,604	91,935	92,313	461,817	7,697	11	12	3	0	18	12	2	2	s.	Good NE.; fair W. to S. sea.
Savannah, Ga.	194	96,267	104,635	95,132	94,278	95,839	486,151	8,102	2	18	2	3	7	19	6	3	sw.	Good 20 miles from ocean.
Jacksonville, Fla.	245	[8] 67,924	109,919	106,739	104,806	104,259	[9] 493,647	[10] 8,227	4	17	1	7	1	24	3	3	sw.	

[1] 8 months.
[2] 9 months.
[3] 53 months.
[4] Mean for 53 months.
[5] 11 months.
[6] Total for 59 months.
[7] Mean for 59 months.
[8] 8 months.
[9] Total for 56 months.
[10] Mean for 56 months.

TABLE 2.—*Velocity (miles per hour).*

Stations.	Mean maximum, by years.					5-year mean.	Absolute maximum, by years.					Number of winds, 50 miles per hour or over, by months.												Total.
	1915	1916	1917	1918	1919		1915	1916	1917	1918	1919	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
Eastport, Me.	44	45	47	43	43	44	NE. 63..	NE. 77..	E. 70....	E. 67	NE. 72..	4	1	7	1	0	0	1	1	0	3	6	4	28
Portland, Me.	39	34	36	38	34	36	NW. 54.	NW. 48.	SE. 60..	NW. 56.	NW. 48.	0	0	1	0	0	0	0	0	1	0	0	2	4
Boston, Mass.	36	35	35	36	34	35	NE. 52..	W. 47....	E-NE. 48.	W. 48....	NW. 43.	0	0	0	0	0	0	0	0	0	0	0	1	1
Nantucket, Mass.	54	47	56	47	46	50	NE. 79..	NE. 67..	SW. 76..	S. 60....	SW. 56..	5	4	3	6	1	0	1	0	3	3	2	12	40
Block Island, R. I.	58	53	54	52	53	54	W. 86....	NW.-W. 72.	E. 76....	NW. 70.	NW. 70.	16	20	20	6	3	0	0	1	2	6	11	24	109
Sandy Hook, N. J.	58	53	57	53	55	55	W. 76....	NW. 65.	S. 73....	NW. 74.	W. 76....	14	14	18	14	2	1	3	6	2	5	8	19	106
Atlantic City, N. J.	32	28	30	30	29	30	NE. 49..	NE. 38..	SE. 44..	NE. 38..	NE-NW. 39.	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape May, N. J.	35	34	35	37	32	35	E. 48....	NW. 50.	S. 48....	S. 52....	NW. 42.	1	0	0	1	0	0	0	0	0	0	0	0	2
Cape Henry, Va.	51	49	47	48	54	50	NE. 74..	NE. 56..	N. 60....	E. 54....	N. 68....	1	5	7	7	0	7	2	3	3	1	1	4	41
Hatteras, N. C.	49	46	47	51	43	47	W. 66....	NW. 64.	NW. 66.	SW. 72..	N. 54....	4	7	5	5	0	3	2	2	0	1	2	7	38
Wilmington, N. C.	32	29	35	34	27	31	S. 43....	W. 38....	SW. 47..	NE. 60..	NE. 36..	0	0	0	1	0	0	0	0	0	0	0	0	1
Charleston, S. C.	37	39	38	36	35	37	SE. 54..	N. 64....	NE. 46..	S.-E. 47.	NE. 51..	0	0	0	0	0	0	3	0	0	0	1	0	4
Savannah, Ga.	46	42	41	37	41	41	SE. 62..	NW. 52.	NW. 60.	SW. 56..	W. 46...	2	4	2	0	1	2	2	0	0	0	1	1	15
Jacksonville, Fla.	47	44	46	44	41	44	SW. 64..	SW. 54..	SW. 60..	SW. 59..	SW. 54..	2	3	1	2	3	2	6	3	0	0	0	1	23

NOTE.—Records for Cape May, Hatteras, and Jacksonville cover 53, 59, and 56 months, respectively; details in Table 3.

TABLE 3.—*Wind velocity and direction.*

Station.	Mean maximum velocity by direction.								Relative frequency by direction.							
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Eastport, Me.	...	46	49	38	44	.....	38	32	0	[1]21	15	5	5	0	5	7
Portland, Me.	30	35	37	39	33	27	31	38	2	9	3	9	5	2	2	[1]25
Boston, Mass.	31	38	34	38	29	30	38	36	4	8	9	2	2	4	[1]19	15
Nantucket	43	51	54	48	45	53	49	43	4	[1]25	3	2	3	19	2	2
Block Island	54	50	54	60	...	35	53	56	1	8	6	1	0	2	12	[1]30
Sandy Hook	50	62	57	60	57	55	63	53	7	3	3	1	11	2	10	[1]26
Atlantic City	19	35	24	30	25	23	26	32	3	[1]15	5	8	14	6	2	13
Cape May	...	30	34	34	45	35	34	33	0	5	5	8	4	1	1	[1]14
Cape Henry	48	49	57	....	48	46	....	49	[1]25	20	3	0	1	1	0	10
Hatteras	47	44	62	55	50	45	45	47	[1]20	4	1	1	4	8	9	15
Wilmington	30	37	24	37	35	31	32	38	4	11	5	2	5	[1]21	10	2
Charleston	38	37	31	35	41	33	38	35	6	[1]21	4	4	9	10	5	5
Savannah	35	44	31	39	38	44	41	43	4	3	10	6	5	3	13	[1]18
Jacksonville	44	41	39	37	44	47	52	45	3	6	2	3	6	[1]20	3	6

[1] Indicates prevailing direction.

NOTE.—Data from the following stations is missing: For Cape May, April, July, and August, 1918; January, February, and March, 1919; for Hatteras, October, 1918; for Jacksonville, January, February, March, and April, 1915.

THE ACCURACY OF WIND OBSERVATIONS IN LARGE CITIES.

By G. HELLMANN.

[Abstracted from Bericht über die Tätigkeit des Preussischen Meteorologischen Instituts in den Jahren 1917, 1918, 1919, pp. 24–29.]

The necessity of observing the direction of the wind from wind vanes has led to the placing of vanes on buildings in cities which are but poorly exposed to the wind, and, being influenced by eddies and deflected currents from adjacent buildings, they not only fail to agree in results with those exposed openly but also disagree with other poorly exposed vanes.

The author has investigated this question for five years, 1911–1915, at three stations located in Berlin. The Urban municipal hospital is located near the south limit of Berlin, the Agricultural high school is 4.5 kilometers northwest of Urban, and a third station located in Seestrasse was 3.1 kilometers northwest of the high school on the northwest limit of Berlin. The relative number of wind directions recorded by the three stations in those years is as follows:

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
Urban	100.4	40.0	142.8	77.6	211.4	172.8	103.8	132.2	24.6
High school	66.4	103.4	126.0	115.0	118.7	163.2	256.5	124.2	22.2
Seestrasse	87.0	112.0	135.2	83.6	158.6	158.0	266.4	84.2	10.6

Most conspicuous in this table are the differences between the three stations with south and with northeast winds. The Urban station recorded about twice as many south winds as the high school, while the Seestrasse station recorded three times as many northeast winds as the Urban station. This is probably due to the situation of these stations with respect to the city. Seestrasse, on the northwest received more northeast winds; Urban, on the south, had a preponderance of south winds.

Of interest, also, are records made between 1775 and 1787 within Berlin, which, then, of course, was much smaller than now. One observer was Beguelin, who observed from the old observatory in Dorotheenstrasse for the Academy of Sciences, and the other was Gronau, the minister of the Parochialkirche, who observed the vane on his church steeple. The two points lay about 1.5 kilometers apart. Their records show very poor agreement as to frequency. The best agreement occurred in the months of May, June, and July when the north wind is prevailing. Throughout the year Gronau had more southwest winds than Beguelin, and, in general, he also recorded more west winds, while Beguelin noted more north, south, and southeast winds.

These records show how unreliable are many of the records of wind direction obtained in cities. The observations of Beguelin and Gronau show also that recording instruments are essential, for their best agreement was in those months when long daylight and clear weather aided their observing in morning and evening.—*C. L. M.*

GROUND TEMPERATURES COMPARED WITH AIR TEMPERATURES IN A SHELTER.

By GEORGE REEDER.

[Weather Bureau, Columbia, Mo., Oct. 19, 1920.]

SYNOPSIS.

A series of observations was made at the United States Weather Bureau Station, University of Missouri, Columbia, during the months of September and October, 1907, to determine how much exposed thermometers on the ground differed from sheltered thermometers 11 feet above the ground. To test the problem further, three beds were made, one of bare soil, one of blue-grass sod, and one of sand. Observations made during the passage of cumulus clouds and upon the effect of a shade area 20 feet distant showed that all the instruments responded to cloud shadows, but that only ground thermometers showed the effect of the building shadow. The latter shadow caused a perceptible movement of air toward the sunlit area. This paper serves to present the collected data from these observations.

RESULTS.

Equipment.—The equipment consisted of maximum, minimum, wet and dry bulb thermometers and a thermograph, in the shelter, and of one minimum and one dry bulb thermometer on each of three beds. The beds consisted of small adjoining plots of bare soil, blue-grass sod, and sand, each 18 inches square. The shelter, which was of the usual Weather Bureau type, stood 11 feet above the ground. The beds lay on the south side of the shelter so that on bright days the shelter shadow was thrown away from the thermometers exposed in the beds. The thermometers were placed, with the bulbs partly, but not wholly, covered, pointing to the north. For protection from interference and accidents, the three beds were covered with a strong 3-inch mesh wire cage, the four corner wires being driven into the ground. The observations were made with the dry bulb thermometers at 2 p. m. and sunset and each morning with the minimum thermometer.

The accompanying tables and diagram show that during September nights bare soil cools slower than either sod or sand. Generally, it was cooler on the ground during clear nights than in the shelter; during calm, clear, dewy nights bare soil was the warmest, as a rule. In the middle of the day during September, under bright sunshine, bare soil and sand went to higher temperatures than the sod; and the temperature changes with the passage of a cloud also were greater on bare soil and sand than on sod. During cloudy, damp weather ground-surface temperatures were moderate and varied but little. The loss of heat from the bare soil surface was quite marked after September 20.

The warmest period was from September 11 to the 19th, inclusive (see fig. 1). The 16th was the warmest

day. On that date soil, sod, and sand, and the shelter started off with about the same temperature, namely, 67.4°, 66.5°, 66.5°, and 69° F., respectively. By 2 p. m., the highest point had been reached, the thermometer on the bare soil reading 121.5°; on the sod, 109°; on the sand, 126°, and in the shelter, 91° F. At sunset, the readings were, soil 82°, sod, 76°, sand, 85°, and shelter, 84° F.

During October nights, soil seems to be more retentive of its warmth. Sand cools more readily, but differs but little from sod in this respect. In the middle of the day, sand is the warmest and sod the coolest. Sand is the warmest under nearly all conditions, even when covered by leaves. After the first week, the sod began to turn a grayish brown.

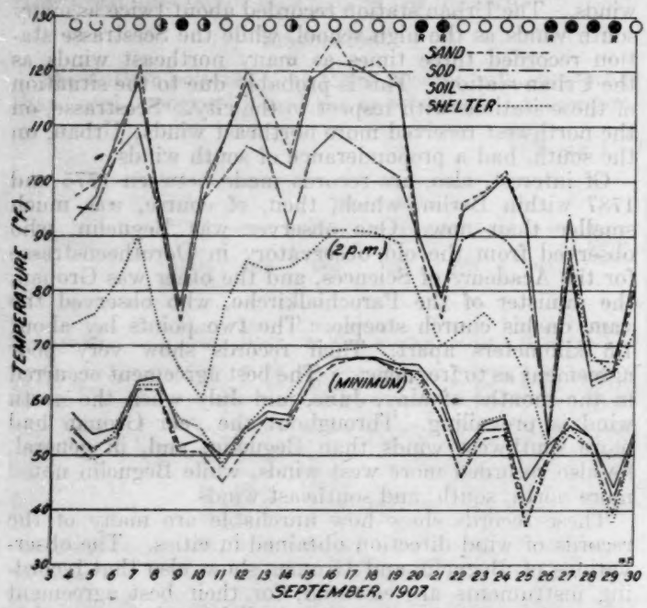

FIG. 1.—2 p. m. (about maximum) and minimum temperatures during September, 1907, in shelter and in various kinds of earth.

The cooling effect of radiation from the thermometer shelter was indicated, as usual,[1] by lower temperatures in the shelter then on ground on clear nights. The first autumn frost seemed to cause more damage several, say 10 to 15, feet above ground than immediately on the ground; tops of small trees, and the tassels and top blades of corn, appeared to be damaged first, evidently because radiation from lower, sheltered portions was limited.

During the middle of the day in October, the air in contact with sod was consistently cooler than the air in the shelter 11 feet above ground; and on one day, the 26th (a rainy day), it was cooler in the shelter than on the ground, including soil, sod, and sand.

Effects of deep shade and passing clouds.—A few observations were made to determine what effect near-by shade and the shadows cast by passing cumulus clouds had on the ground-surface thermometers during a warm September spell.

A building south of my experimental plot cast a deep shade within about 20 feet of the thermometers on the ground. During the hot spell of September, there was a noticeable movement of air on the ground from the shade out into the sunlit area. This was determined by placing light feathers just inside the shade line. During the hot relatively calm days these feathers moved out into the warm area as far as and beyond the thermometer beds. The instruments were sensitive enough to respond to the cooler shade air.

During passing cumulus clouds the drop in temperature was marked, and this serves to show that every passing cumulus cloud in summer, when it is dry and hot, affords relief to the parched hot earth. It will be noticed that passing clouds not only caused a drop in temperature as recorded by the ground thermometers, but also affected the shelter temperature, although to a smaller extent. The movement of the cooler ground shade air, however, only affected the ground thermometers, the air in the shelter showing no change.

TABLE 1.—*Temperatures on various types of days.*

	Rain.			Clear.					
				Wet ground.			Dry ground.		
	Minimum.	Maximum (2 p. m.).	Sunset.	Minimum.	Maximum (2 p. m.).	Sunset.	Minimum.	Maximum (2 p. m.).	Sunset.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
Soil	53.1	63.9	55.0	50.9	94.5	64.0	66.5	117.5	83.9
Sod	53.6	67.9	54.0	50.0	89.5	61.0	66.0	101.0	77.9
Sand	51.5	67.9	54.5	46.0	96.0	65.9	65.2	117.0	85.0
Shelter	51.3	68.1	53.1	46.0	73.0	66.0	66.6	89.0	83.8

TABLE 2.—*Temperatures at time of first killing frost.*

	Oct. 11, sunset.	Oct. 12, minimum.	Fall.	Oct. 12, sunset.	Oct. 13, minimum.	Fall.
	° F.	° F.	° F.	° F.	° F.	° F.
Soil	47.2	35.5	11.7	44.9	31.6	13.3
Sod	44.1	31.6	12.5	41.0	29.5	11.5
Sand	49.0	30.7	18.3	46.0	26.3	19.7
Shelter	52.8	32.0	20.8	47.5	25.5	22.0

TABLE 3.—*Monthly averages of temperatures.*

	September.			October.		
	Minimum.	Maximum (2 p. m.).	Sunset.	Minimum.	Maximum (2 p. m.).	Sunset.
	° F.	° F.	° F.	° F.	° F.	° F.
Soil	57.5	97.7	69.7	45.1	68.9	52.5
Sod	56.2	92.1	65.7	43.0	66.2	51.3
Sand	54.6	97.6	70.4	42.8	71.2	54.3
Shelter	53.6	77.0	71.4	44.9	64.1	58.3

TABLE 4.—*Temperatures in bright sunshine, and when the sun is obscured by cumulus clouds.*

Sept. 15.	Bright sunshine immediately preceding cloud.	Sun covered 4m 6s; fell to—	Amount of fall.	4m 6s of bright sunshine immediately following cloud.	Amount of rise.
	°F.	°F.	°F.	°F.	°F.
Soil	119.0	111.0	8.0	116.2	5.2
Sod	106.0	100.0	6.0	102.0	2.0
Sand	119.0	110.0	9.0	113.8	3.8
Shelter	87.0	86.0	1.0	86.2	0.2

Wind velocity, m. p. h., 2; direction, south.

[1] Cf. MONTHLY WEATHER REVIEW, February, 1918, 46: 69-70; May, 1920, 48: 271-272.

The following comparative readings were made under similar conditions, except the sun was covered 5m 30s.

Sept. 18.	Bright sunshine immediately preceding cloud.	Sun covered 5m 30s fell to —.	Amount of fall.	5m 30s of bright sunshine immediately following cloud.	Amount of rise.
	°F.	°F.	°F.	°F.	°F.
Soil	122.2	111.0	11.2	119.0	8.0
Sod	108.0	99.5	8.5	103.7	4.2
Sand	122.0	113.0	9.0	121.8	8.8
Shelter	90.0	88.2	1.8	90.3	2.1

Wind velocity, m. p. h., 2; direction, south.

Comparative readings in bright sunshine every 15 minutes, Sept. 16

	1:00 p. m.	1:15 p. m.	1:30 p. m.	1:45 p. m.	2:00 p. m.	2:15 p. m.[1]	Average variability.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Soil	118.0	119.5	121.5	121.5	121.5	119.5	1.9
Sod	109.0	108.5	109.0	107.5	109.0	104.5	1.4
Sand	121.5	121.5	125.0	125.5	126.0	122.0	1.5
Shelter	89.0	89.0	89.5	91.0	91.0	91.0	.....

Wind velocity, m. p. h., 2; direction, southwest.

Comparative readings in bright sunshine every 5 minutes, Sept. 17 and 18.

Sept. 17.	2:15 p. m.	2:20 p. m.[1]	2:25 p. m.	2:30 p. m.	2:35 p. m.[1]	2:40 p. m.[1]	Average variability.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Soil	119.5	119.0	119.5	120.8	107.0	104.2	3.1
Sod	104.5	104.2	105.0	106.0	104.0	101.0	1.2
Sand	122.0	121.0	121.9	124.8	121.0	118.0	1.9
Shelter	90.4	90.4	91.0	91.6	91.6	90.9	0.2

Wind velocity, m. p. h., 3; direction, southwest.

Sept. 18.	1:30 p. m.	1:35 p. m.[2]	1:40 p. m.	1:45 p. m.	1:50 p. m.	1:55 p. m.[1]	2:00 p. m.	Average variability.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Soil	118.0	114.0	116.6	119.7	119.0	117.0	121.0	2.2
Sod	105.0	102.0	103.9	106.0	106.0	104.0	106.5	1.6
Sand	118.0	113.3	117.0	119.0	118.8	116.2	120.0	2.4
Shelter	90.0	89.0	89.0	90.0	90.9	90.9	91.0	.....

Wind velocity, 2; direction, south.

[1] Movement of cooler shade temperature to thermometer beds.
[2] Passing cumulus cloud.

THE COOLING OF THE SOIL AT NIGHT, WITH SPECIAL REFERENCE TO LATE SPRING FROSTS.

By T. BEDFORD FRANKLIN.

[Abstracted from *Proceedings of the Royal Society of Edinburgh*, session 1919-20, Vol. XL, Pt. I, pp. 10-22.]

In a previous paper[1] Dr. Franklin came to the conclusion that the temperature of the surface of open cultivated soil fell rapidly at the beginning of a calm, clear night, until it was such a number of degrees below the temperature at the 4-inch depth as to make the upward conduction from that depth to the surface balance the radiation. After this stage was reached the surface and 4-inch temperatures fell at the same rate.

If, therefore, the temperatures of the surface and 4-inch depth and the conductivity of the layer of soil between the 4-inch depth and the surface were known from readings of electrical resistance thermometers, and the rate of radiation was calculated from the value of the relative humidity, he suggested that it might be possible to forecast the minimum soil temperature for a calm, clear night as early as the previous afternoon.

In this second paper Dr. Franklin gives a formula for forecasting the minimum surface-soil temperature and compares this minimum with the air temperature immediately above.

He found that the conductivity of this surface layer of soil varied so greatly with different degrees of wetness that an average value could not be used. He therefore has adopted, instead, the ratio of the range of temperature at the 4-inch depth and at the surface, which he expresses by $\frac{R_4}{R_0}$.

The quantities required for the forecast equation are:

(1) The value of $\frac{R_4}{R_0}$ from minimum to maximum, which can be obtained by about 5 or 6 o'clock p. m.

(2) The lag on the day in question; this may be observed by about 5 or 6 p. m., or may be found from the values of $\frac{R_4}{R_0}$.

(3) The estimated relative humidity of the coming night.

(4) The number of degrees (θ) which the surface can fall below the 4-inch temperature before the upward conduction balances the radiation; this depends on $\frac{R_4}{R_0}$ and the relative humidity.

(5) The probable difference between the air minimum over open-soil and the surface-soil minimum.

1. Observations show that the ratio of $\frac{R_4}{R_0}$ averages 0.42 immediately after a rain and 0.23 in dry soil. Intermediate results were found with varying amounts of soil moisture. These figures are for the particular soil and location where the records were taken. Dr. Franklin believes that only slight variations would be found at different places in the same type of soil. While he has not fully investigated the ratio in different soil types, he is of the opinion that the ratio will vary between 0.44 and 0.28 for loam, 0.60 and 0.41 for sand, and 0.41 and 0.35 for clay under similar weather conditions.

2. The lag between the 4-inch and the surface temperatures varies from 3½ hours when $\frac{R_4}{R_0}$ equaled 0.44 to 5½ hours when the ratio was 0.20 and was fairly proportioned between these ratios.

3. The connection between $\frac{R_4}{R_0}$, the relative humidity, and the number of degrees centigrade (θ) which the surface can fall below the temperature of the 4-inch depth before the upward conduction balances the radiation is shown in the following table:

Values of θ in °C.

Relative humidity.	Values of $\frac{R_4}{R_0}$							
	0.30	0.32	0.34	0.36	0.38	0.40	0.42	0.44
90 per cent	8.0	7.5	7.0	6.5	6.0	5.5	5.0	4.6
80 per cent	8.7	8.1	7.6	7.0	6.5	6.0	5.5	5.0
70 per cent	9.5	8.9	8.3	7.7	7.1	6.6	6.1	5.5
60 per cent	10.2	9.6	9.0	8.4	7.8	7.2	6.6	6.1

[1] See review in MONTHLY WEATHER REVIEW, Dec., 1919, 47: 849.

4. On 10 nights when the surface of the ground was frozen the air temperature varied from 3.2° to 0.3° (C.) lower than the surface-soil temperature, with an average of 2.7° (C.) cooler. On 28 nights when the surface did not freeze the air temperature minimum averaged 0.4° (C.) higher than the surface-soil temperature, the variation being from 1° higher to 1° (C.) lower. It follows, therefore, that when the surface of the ground does not freeze the air minimum over open soil follows the surface-soil minimum very closely.

In a later paper in the same publication (pp. 56–79) Dr. Franklin discusses soil temperatures further under the head, "The Effect of Weather Changes on Soil Temperature." The following are brief quotations from this article:

In comparison with the variation of surface temperature, the regular pulsations of temperature underground follow well-known laws for amplitude and retardation according to depth; but in these regular pulsations there are minor fluctuations which occur either day by day or at irregular intervals, according to the weather and the state of the surface soil.

Of these minor fluctuations the most important are due to the percolation of rain, the movements of soil air and moisture, the presence of a dry surface mulch, the prevalence of strong winds of low relative humidity, or the occurrence of frost and snow. * * *

Rain is a great equalizer of temperature between the surface and underground—in fact, it is probable that the first rise of temperature underground from the low level of winter is due to warm spring rains. * * *

Snow is an extremely bad conductor, and as little as 4 inches of snow provides a complete protection for the surface from very large variation of temperature above the snow surface. * * *

It is obvious that so long as the air temperature was above −15° C. thawing must have been going on constantly at the bottom of the snow layer, this thawing being the more rapid the more the air temperature rose.

The coming of spring.—Spring, considered as the beginning of the period of active growth of crops, depends in the main on the soil temperature at the depth at which these crops grow. At first sight it would appear a simple matter—with the meteorological data for any year before us—to say whether that year had enjoyed an early or late spring; but when we study the phenological returns for the last 30 years the question assumes a more complex appearance.

If we plot the deviations from the normal of the date of first flowering of any plant against the corresponding deviations from normal for some chosen preceding period of the values of the mean, maximum, minimum, or soil temperatures, we do not find the closely corresponding results that we may have expected. As, however, mean values cover a multitude of variations, this is not to be wondered at, and it is doubtful if any good result can be obtained from monthly mean values at all. For let us consider two extreme months—

(1) With a very small range of temperature and a mean equal to the average.

(2) With a spell of frost for, say, 15 days, and very warm weather for 15 days, and a mean above the average.

Now, if the growing temperature for the plant considered was below the mean for the month, No. 1 would give nearly 30 growing days, and the plant would appear in flower earlier than in No. 2, which gives only 15 growing days, although the mean temperature of No. 2 is higher than of No. 1.

Thus not only the growing temperature of the plant, but the daily values that make up the mean, have to be known before we can make any rule for the behavior of the plant under the given conditions, and the date when the minimum soil temperature at from 4 to 6 inches depth passes the growing temperature of the proposed crop is the real question that concerns the cultivator.

If we take 5.5° C. as the average growing temperature of most crops, it is of interest to note how weather changes help forward or retard the arrival of this temperature in the soil at 4 inches depth.

In March and April, 1919, there was a succession of spells of very different weather, which showed by their influence on the 4-inch depth temperature that it is the overcast weather, with bright intervals and overcast nights, that most rapidly increases the temperature underground, and not, as might be expected, the bright, sunny weather with clear sky and low relative humidity.

These figures (omitted) emphasize the importance of the effect of frost and clear nights on underground temperatures: in fact, we may say that the soil temperature for any period in winter or spring is mainly dependent on the number of frosts which occur while the ground is open without deep-lying snow during that period. Frosts that occur when several inches of snow is lying have, as we have already seen, little effect on soil temperature, owing to the great protection given by the snow. * * *

Conclusions.—1. The values of $\frac{R_4}{R_0}$ have a wide range of variation, from 0.19 in very dry soil to 0.85 during heavy rain; the most common value is about 0.40. The monthly mean values showed a decided connection between $\frac{R_4}{R_0}$ and the frequency of rainfall; in fact, percolation of rain seems to be the dominating factor in deciding the value of $\frac{R_4}{R_0}$. This is also borne out by the different values of $\frac{R_4}{R_0}$ in various soils according to their behavior with regard to water; in sand the values change with mercurial rapidity, due to the easy percolation of rain and subsequent rapid drying, while in clay they change but sluggishly, since clay takes up and parts with water with difficulty.

2. In view of the fact that the values of $\frac{R_4}{R_0}$, and therefore the values of the diffusivity of the soul, are so dependent on the percolation of rain, it is possible that the values commonly given for the diffusivity of the surface layers of the earth need revision.

3. Underground temperatures are also considerably affected by—

(*a*) Strong winds of low relative humidity.

(*b*) The frequency and intensity of frost when the soil has no snow covering.

(*c*) The depth of snow.

(*d*) Weather changes of long period.

4. The date of flowering of Coltsfoot appears to bear little relation to the monthly mean values of temperature, but is closely related to the number of frosts on open soil not covered with deep snow. It is possible that good results would be obtained by comparing the phenological returns of the last thirty years with the accumulated temperature underground above the growing temperature for each plant considered.

—*J. Warren Smith.*

EFFECT OF SOIL ON FROST DAMAGE.

In a letter to *Science* (Mar. 28, 1919, pp. 310–311), Mr. T. G. Dabney describes the effect of the onslaught of a killing frost upon vegetation growing upon soils of different character. It was observed that cotton growing in the river silt near the old river bank of the Mississippi was not damaged, but that that growing back from the river bank in the heavy clay, known locally as "buckshot," was completely killed. The explanation offered was that the radiation from the silty soil during the cold night was sufficient to protect the plants, while the clay did not possess this property. The cold night was not preceded by other cold ones but came suddenly when the soil was warm. The country in the vicinity was very level.—*C. L. M.*

PREDICTING MINIMUM TEMPERATURES FROM THE PREVIOUS AFTERNOON WET-BULB TEMPERATURE.

In Geografiska Annaler, January, 1920 (pp. 20–32), Anders Ångström, of Upsala, Sweden, under the title "Studies of the Frost Problem, I," shows that very close minimum temperature forecasts can be made on comparatively clear nights by subtracting a constant from the wet-bulb temperature.

The constant was smallest and the percentage of accuracy highest when the observation of the wet-bulb temperature was made at about sunset, but fairly close predictions resulted from observation at other afternoon hours, even as early as 1 p. m. The constant varies with different hours and different months; Dr. Ångström found it to be greatest at 3 p. m.

The discussion shows "that the minimum temperature may be obtained through subtracting a constant value from the temperature of the wet bulb at sunset multi-

plied by a constant factor and diminished by the temperature of the dry-bulb thermometer multiplied by a certain factor." He found, however, that the factor which ought to be applied to the temperature of the wet thermometer is very nearly equal to 1 and further that the temperature of the dry thermometer enters with a factor that is not large. This leaves the equation $T_{min.} = t_1 - k$, or the wet-bulb temperature minus a constant (k) as indicated above.

The author says in closing, "* * * : Still there are some important factors left, which in a high degree influence the cooling of the ground and which need to be more thoroughly considered. I allude to the conductivity, heat capacity, and temperature gradient of the ground, which all are important causes of the local variations in minimum temperatures found at places situated near to one another. Great progress in our predictions of temperature changes of the ground will never be possible until these last-named problems are seriously attacked."

Dr. Franklin's investigations reviewed (above or on pp. 639–640) cover the points referred to by Dr. Ångström.—*J. Warren Smith.*

PROBLEMS ON THE RELATION BETWEEN WEATHER AND CROPS.

LLOYD D. VAUGHAN.

[Tiffin, Ohio, Nov. 24, 1920.]

For any crop of grain, fruit, or vegetables to come up to what is known to be its maximum yield, it must have whatever is correct in the way of soil conditions as regards fertility, drainage, etc., the proper care in planting and cultivation, and be favored by the kind of weather conditions which may happen to be suited to its requirements. The weather is by far the most variable and uncertain of the three and the study of its relation to crop growth presents a multitude of problems, the complete solution of which can not fail to be of considerable benefit to practical agriculture.

By the solution of these problems the relation between the weather and crops can be established on a quantitative basis, so that we may know the exact reason for any particular seasonal result for a certain crop and understand the connection between the coincident numerical values of crop growth or yield and weather conditions.

The following notes and list of problems will show that a great many observations and experiments of a special nature are required in this work if the results are to be of any real or permanent value. It would be advisable for this investigation to cover each locality where any of these conditions are different from those of another for it to include as many of these separate localities as possible.

1. *Temperature.*—(*a*) Observation of the daily range of temperature, or its variation in value during the full period of 24 hours. Data on the average daily temperature are required for this purpose rather than the instantaneous values noted but two or three times at certain hours during the day.

(*b*) Surface temperatures of the soil under variant conditions.

(*c*) Difference between soil and air temperatures.

(*d*) The amount of sunlight and radiation received and the presence of haze or cloudiness.

2. *Humidity.*—(*a*) Humidity, its relation to other weather factors and their combined influence on plant growth.

(*b*) The study of the sequence of changes in daily temperature, himidity, etc., from which predictions for minimum temperatures or frost conditions can be made.

3. *Rainfall.*—(*a*) Duration, or the amount falling within a certain time. This study is important in order to determine the effect of any quantity of rain on plant growth. It is very unlikely that 1 inch of rainfall in a period of one hour would be of as much benefit to a crop as would the same amount distributed over a three- to six-hour period.

In other words, the element of time as well as quantity should be taken into account and a record kept of this relation, so that by this or other means it may be possible to compare the total hours and inches of rainfall with the growth or yield of any crops.

(*b*) It is also important that a special note should be made of the time or part of the day when the precipitation occurs, and also of the soil conditions, temperature, sunshine or cloudiness, etc., immediately preceding, and for several hours following, any appreciable rainfall during the growing season.

(*c*) Temperature of catch.

(*d*) Evaporation rates, etc.

(*e*) Difference between soil and air moisture.

(*f*) The absorption of rainfall by soils and relative effect on plant growth.

4. *Effect of low temperatures on wheat and clover.*—There are three principal causes of the winter killing of these crops: (1) Smothering under an ice sheet, water, or packed and frozen snow; (2) heaving out by alternate freezing and thawing; (3) freezing by long-continued cold while having no protection.

Wheat seems to be able to withstand cold to temperatures possibly 10 or more degrees below freezing, but when these temperatures remain this low for any great length of time the plants, especially those near a crack in the soil, or which have their crown and roots exposed by the action of the wind and previous thawing, are likely to be frozen unless protected in some way.

A large total of snowfall during the dormant stage does not furnish a very reliable condition on which to depend as being the reason for the favorable outcome of this crop through the winter months.

The number of days showing the presence of snow enough to cover the plants completely may be a better indication, but as is sometimes the case the wheat may be well covered with snow through the major portion of the winter, when along toward spring there are a few days of thawing followed by a week or two of very cold weather, while the ground is nearly bare, which will discount the advantage gained through being protected all winter. The important point is that the ground should be covered with snow during the time that any conditions exist which may have an unfavorable effect on the winter survival of wheat, clover, and similar crops.

The kind of soil, the amount of moisture and organic matter contained therein, surface and under drainage, and the fall growth of these plants also have considerable to do with their survival through the winter season.

Data are needed in regard to the most favorable or unfavorable winter conditions for wheat, clover, various fruits, etc., as to the different ways in which they may be affected by the weather in combination with various modifications of the other factors named above. Also

on the frequency of freezing and thawing, depth of freezing, the rapidity of change of temperature, and the extent of this variation.

5. *Correlation of weather and plant growth.*—(*a*) Comparison of yields of various crops with complete records of the weather conditions associated with them.

This study should cover as long a period and include as many sets of conditions as possible, in order to determine the normal values of both weather factors and crop yields and to learn the cause and effect of any departure from these normal values.

(*b*) Effect of weather conditions on the germination of seed, early growth, blossoming, formation of grain or fruit and the maturing of various farm crops.

More complete data are needed as to the effect of weather on the time of blossoming, formation of grain or fruit and the ripening of these different crops. Also in regard to the quality of grain, fruit, vegetables, etc., as related to the particular weather conditions experienced during the season in which they were grown.

(*c*) The daily, monthly, or seasonal distribution of temperature and precipitation as related to its effect on plant growth and the total heat, sunshine, and rainfall required to bring about a certain stage of growth and to produce and mature a full crop in the average time usually considered to be the growing season of any of the different crop plants.

(*d*) Physical and physiological studies of plants compared with weather. The combined influence and proportional effect of all the different factors of climate and weather on the development of any crop, as shown by continual observations of the rate of growth and extent of changes produced in the plant itself, from the time of planting until harvest.

6. The effect of temperature, sunshine, and precipitation on the activity of nitrogen bacteria and other soil organisms which are essential to plant growth.

7. The solubility of different carriers of nitrogen, phosphorus, potash, and other plant food elements, and the degree to which any plant may be able to utilize these elements, as dependent on the weather, or the temperature and moisture conditions of the soil during the season.

8. The effect of the weather on the propagation and natural control of insect pests and plant diseases. The damage done to crops by the chinch bug, Hessian fly, potato blight, various rusts, smut, and many other insects and diseases affecting fruit and grain crops depend to a great extent on the particular kind of weather experienced during certain periods of the year.

9. The influence of the weather on the prevalence and spread of animal diseases. There is already some evidence that many diseases of farm live stock, particularly those of a contagious nature, are subject to certain favorable or unfavorable weather conditions.

10. Mathematical analysis or correlation of the data collected on the relation of different meteorological factors to plant growth.

There are, no doubt, many other problems which could be added to this list, but it is intended only to point out the different groups of problems and the several lines of investigation which could be carried on by our experiment stations or other institutions where complete records are kept of the results of other investigations relating to agriculture.

Now the question may be asked, what practical value can be expected to be derived from the investigation of these problems, since the weather conditions which may cause either the success or failure of a crop must necessarily be a thing of the past before their effect can be studied.

One answer to this question is found in the fact that a clear knowledge of the effect of different weather conditions on crop plants at various stages of growth, may afford a fairly accurate idea of what effect any of these conditions might have on the subsequent development of a crop, and from this a better forecast can be made as to its final outcome and any dependent plans can therefore be made or changed accordingly.

If we should have the same range of temperature and receive the same amount of light, heat, and precipitation at the same particular time each year, and if this should occur year after year in a uniform annual cycle, then both experimental and practical agriculture would probably be reduced to simply a matter of difference in soils, seeds, fertilizers and culture, because then we should have some way of knowing about what results were to be expected each season.

But since the different weather factors vary greatly from one year to another, both as to quantity and quality and in their geographic and seasonal distribution, there is always a different combination of circumstances surrounding the growth of each year's crops.

These different sets of conditions may affect the growth of a plant in so many different ways that it is only by means of a well planned and extended series of careful field observations and the mathematical correlation of their results that we can expect to eliminate the uncertainity concerning the effect of any particular set of conditions on the life history of a plant and to apply these principles toward improving our systems of soil treatment, varieties, and the methods of culture and handling of any crop.

Perhaps no very radical improvement can be made, but it seems reasonable to expect that this knowledge should tend to increase the efficiency of our methods.

In any experimental fertility work, for instance, without accurate data in regard to the effect which various weather factors may have on soils and on plant growth, it is often quite difficult to determine just what part of the annual variations in the ratio between the results from two or more plots in a compatative test may be due to differences in soil treatment or to differences in the character of the weather conditions.

A certain kind, quantity, or combination of fertilizers, or a certain variety of grain or method of culture, may show an apparent advantage one year; while during the next year or two the seasonal conditions may be such as to cause the result to be entirely reversed and possibly another treatment or variety may return the most profit.

Or, as it is often the case, a crop of corn may not ear up well, or the wheat, oats, or clover may not grow or fill as it should, and again the potatoes or fruit may be subject to some unfavorable influence of the weather during the time of blossoming, ripening, or other critical periods of their growth.

The real cause of all these effects are usually only guessed at and several plausible explanations may be offered, but it would often be quite profitable to know the exact reason for them, as well as those which may cause a very good growth and yield.

It is well known that the compa ative merits of different varieties, cultural methods and fertilizer treatments can only be learned from the average of results covering possibly ten or more years of experiment, but it should be obvious that a more exact approximation could be

made if complete and reliable data were available concerning the relation of the weather to any irregular or annual variations in these tests.

The success or failure of a year's work is dependent on the amount in which the crops may be favored by the weather, and although the farmer has no means of control over this element, there may be found several ways in which it is possible to take advantage of seemingly unfavorable conditions.

For this reason any facts which may be established through the investigation of these problems will help to give us a scientific knowledge of the different relations between weather and crops, and this knowledge put in workable form will enable agricultural experimenters, students, and farmers to clear up many things which are so little understood at this time, and thereby greatly improve the present status of agricultural practice.

THE INFLUENCE OF METEOROLOGICAL PHENOMENA ON VEGETATION.

Revue Scientifique, February, 1920, pp. 115-116.

Translated by KATHARINE DAVIS.

Dr. Azzi, of the University of Rome, has studied the relations existing between the critical periods of vegetation and meteorological phenomena. His method consists of observing at the same time the biological phenomena which dominate the life of plants and the meteorological phenomena which react on them with the greatest intensity. (Treatise presented by M. G. Wery to the Academy of Agriculture.)

Vegetation presents critical periods which are controlled by meteorological phenomena, rain, humidity (moisture), frost, heat, and dryness. Each period corresponds to a particular phase in the life of the plant; thus the critical period of vegetation of wheat with respect to rain is that, of variable duration, when this cereal requires, absolutely, a minimum of water. If rain does not fall at the precise time when the grain is in this critical period with respect to water, its development is hindered and the yield will be diminished.

In the same way for fruit trees, if the heat which is necessary for them in the corresponding critical period is less than they require, the crop will be decreased. (Leaf of Information of the Minister of Agriculture.)

Knowing the critical periods, it is necessary to know what are the mean epochs of the year when these occur for each one of the cultivated plants, epochs which vary with the region. One may then draw charts to which the author has given the name phenoscopic charts.

For each cultivated plant there are as many phenoscopic charts as there are critical periods and decisive meteorological factors; thus, there are four for grains relative to humidity (moisture); germination, earing, flowering, and maturity of grains.

Dryness being recognized as the determining cause for diminished return of grain crops in a particular zone, three methods are possible to agriculturists for offsetting this condition. (1) To avoid the phase of vegetation to which the critical period corresponds by modifying the time of seeding; (2) by modifying artificially the meteorological conditions during the critical period by irrigation if that is possible; and (3) to select grain in such a way as to obtain a variety which will resist the injurious meteorological phenomenon, dryness for example.

Phenoscopic charts may, then, assist to a knowledge of climatic conditions as geological charts assist to a knowledge of the soil and consequently of fertility.

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THE INFLUENCE OF COLD IN STIMULATING THE GROWTH OF PLANTS.

By FREDERICK V. COVILLE.

[Abstracted from *Journal of Agricultural Research*, vol. 20, No. 2, Oct. 15, 1920.]

It is the general belief that dormancy in winter of our native trees and shrubs is brought about by cold weather, and that warm weather is of itself sufficient to start new growth in spring. Mr. Coville shows that both of these ideas are erroneous. From a number of very interesting and instructive experiments with blueberry plants under controlled conditions, it is shown that cold weather is not necessary for the establishment of complete dormancy and that after it is established the exposure of plants to ordinary growing temperatures does not suffice to start them into growth; also that plants will not resume normal growth in spring unless they have been subjected previously to a period of chilling. Finally, a theory is advanced to explain this paradoxical effect of cold in stimulating growth. The subject is presented in a series of numbered statements, with supporting evidence in each case.

Healthy blueberry plants were put into a greenhouse at the end of summer and kept at ordinary growing temperatures, but they gradually dropped their leaves and finally went into a condition of complete dormancy. The only difference between the behavior of the indoor and outdoor specimens was a tardiness of the former in assuming dormancy, probably due to a lack of injury to the foliage by freezing temperature.

Plants that were kept continuously warm during the winter started into growth much later in spring than those that were subjected to a period of chilling, while some that had been outdoors during the winter were brought into the greenhouse in early spring. The latter burst into leaf and flower luxuriantly, while the former remained completely dormant. In some cases, plants remained dormant a whole year under heat, light, and moisture conditions favorable for luxuriant growth. As a further test of the matter, some of the branches of a plant were extended through an opening in the greenhouse in one case, and in another the plant was placed just outside with some of the branches extending into the house. When spring came the outdoor branches, in both cases, put out leaves promptly and normally, but the interior branches remained dormant.

In explanation of these phenomena, Mr. Coville points out that the stimulating effect produced on dormant plants by cold is intimately associated with the transformation of stored starch into sugar. Stated in terms of simplicity, stripped of technical phraseology, the theory advanced in explanation of the formation of sugar during the process of chilling is that the starch grains stored in the cells of the plant are at first separated by the living and active cell membranes from the enzym that would transform the starch into sugar, but when the plant is chilled the vital activity of the cell membrane is weakened so that the enzym "leaks" through it, comes in contact with the starch, and turns it into sugar.

Mr. Coville recognizes that the hypothesis of transformation of starch into sugar by the weakening of cell membrane and the consequent leakage of starch-transforming enzyms into the starch chambers may very properly be challenged. In the Tropics there is no chilling weather, yet some trees and shrubs alternate from a state of dormancy to active growth, much as in cold climates. As a probable explanation of this, Mr. Coville points out that injury, such as pruning or girdling, to a long-dormant plant will often start it into growth, possibly caused by enzym being brought into contact with the starch as a direct result of the breaking and straining of the cells. Sugar is then formed and growth begins. This phase of the question is discussed in considerable detail, with the conclusion that the awakening from dormancy to growth in tropical plants may result from cell injury caused by the long dormant period.

The twigs of trees and shrubs, after their winter chilling and the transformation of their starch into sugar, are regarded as mechanisms for the development of higher osmotic pressures which start the plant into growth. Finally, the importance of the establishment of a dormant condition before the advent of freezing weather, and the continuation of this dormancy through warm periods in late fall and early winter, as a protective adaptation to the native trees and shrubs, is pointed out. If plants were so constituted as to start into growth as readily in the warm periods of late fall as they do during similar periods in early spring, the result might frequently be disastrous.—*J. B. K.*

RELATION OF WEATHER TO FRUITFULNESS IN THE PLUM.

By M. J. DORSEY.

[Review-summary of paper No. 162, Journal Series, Minnesota Agricultural Experiment Station.[1]]

Owing to the fact that fruit buds usually appear in the plum in sufficient abundance to produce a full crop of fruit with favorable development, and the further fact that the intervening period between the beginning of blossoming and the setting of fruit is of short duration, the question can be approached with confidence of success in an attempt to isolate definitely the weather factors influencing the setting of fruit.

The study is based on meterological and fruiting data collected during a period of 7 years, 1912 to 1918, inclusive. The data are presented in graphic form by means of diagrams showing the influence of wind, temperature, sunshine, and rainfall during the blooming period on the setting of fruit, and are presented for each blooming period and for 10 days thereafter.

In some experiments cited, it was found that no fruit set from wind-carried pollen when insects were excluded. Therefore, wind may be regarded as having a more indirect than direct bearing on the setting of fruit, in that its influence upon bee flight may be serious at certain times, bees being the chief polinizer of the plum.

Temperature is considered of primary importance from three standpoints: Its effect upon pollen or pistil, its influence upon pollen-tube growth, and its interference with bee flight. In some experiments pollen was not destroyed by exposure to freezing temperature. With an exposure to a temperature of 29.3° F., 56 per cent of plum pollen germinated, compared with 62 per cent when exposed to temperatures above freezing. On the other hand, 21 plum pistils exposed to similar low temperatures for six hours were all killed, except two. Also the time required for germination was considerably increased as a result of low temperature. The action of low temperature in retarding pollen-tube growth is considered as one of the principal causes of the failure of fruit to set, as it was shown that plum pollen does not germinate at temperatures below 40° F. and even at 51° F. there is slow pollen-tube growth. It is pointed out that individual bees can control muscular movement only with temperatures 45° F. or higher, and that, in general, they will not leave the hive when the temperature is below 60° F.

Investigations were cited to show that while sunshine has a direct influence on the fertilization of the tomato, it apparently has none on the plum. Judging from these experiments, sunshine appears to have the chief bearing in this connection on such factors as insect flight and general plant activity, particularly nectar secretion.

On account of the nature of the processes taking place at blooming time, rainfall was found to have a more direct effect than any of the other weather elements. The fact that the period of pollination in the plum is so limited makes it possible for rain to delay normal functioning to an injurious extent. A study of the bloom in the orchard during a heavy and prolonged rain showed that the stamens were drawn together and held in a cluster about the pistil by a large drop of water, especially in the absence of wind. In order to study another action more in detail at the time of rain, a limb which had been in bloom for three days was cut from the tree during a heavy rain and brought into the laboratory, the temperature of which was about 68° F. All anthers were closed when first brought in, but some opened completely in 10 minutes, but when again placed in water they closed in two or three minutes.

The conditions which close anthers frequently prevent insect flight, but even if insects were working, pollination could not take place for the reason that pollen is not available. It appears, therefore, that too much emphasis has been placed upon the action of rain in washing the pollen away, because anthers largely close quickly enough to prevent it. In addition to the above, the effect of water on other organs of the plum flower and their functioning process is discussed in considerable detail.

In summarizing, it is pointed out that unfavorable weather at blooming time may completely prevent the setting of fruit, even though there be a full bloom, and that rain and low temperatures are the most important factors, although strong wind when prolonged is harmful. Wind has its influence indirectly by interfering with insect action, but is seldom strong enough to cause direct mechanical injury. Frosts during bloom injure the pistil more than the pollen, but the greatest damage from low temperature is in the retarding of pollen-tube growth. Cloudiness has no injurious effect in the setting of fruit, but rain prevents pollen dissemination by closing the anthers or preventing them from opening. In one season, rain during bloom may be the limiting factor and in another low temperatures during the period of tube growth.—*J. B. K.*

[1] Shorter abstract published in MONTHLY WEATHER REVIEW, May, 1920, 48: 285.

FORECASTING PRECIPITATION IN PERCENTAGES OF PROBABILITY.*

By CLEVE HALLENBECK, Meteorologist.

[Weather Bureau Office, Roswell, N. Mex., Oct. 15, 1920.]

SYNOPSIS.

During the irrigating and alfalfa-harvesting periods the Weather Bureau office at Roswell, N. Mex., issues an amplification of the forecast, in which the probability of rain within 36 hours is expressed in percentages; 100 per cent representing absolute certainty of rain, and 0 per cent absolute certainty of fair weather.

The basis of this method is a series of composite weather maps showing the frequency of precipitation, in percentages, with different types of pressure distribution. These maps are used only for reference, and are used in conjunction with the daily weather map. The percentage of probability of rain, as shown on the composite map, is usually modified—sometimes ignored altogether—in the forecast issued.

Since, during the warmer months of the year, neither rain nor fair weather can often be forecast for this district with absolute certainty, this style of forecast is of value to the farmers in governing irrigation, and also, to a certain extent, in the harvesting of alfalfa.

Some three years ago the writer submitted to the local press a brief article explaining the terms used in weather and temperature forecasting, and therein it was mentioned incidentally that the element of doubt in the forecasts, which at present is roughly approximated by the use of the qualifying words "probably" and "possibly," can usually be evaluated on a numerical scale. This statement was a fortunate or an unfortunate one, depending upon how the matter is viewed, for it seemed to interest several of the clientele of this station, who claimed that such forecasts would be of more value to the agricultural interests of the Pecos Valley than the forecasts as usually worded. In fact, there has been a vague demand for just such forecasts for several years, as the usual inquiry made by the farmers of this district has always been, "What are the *chances* of rain?"

During six months of 1919 a method of forecasting the probability of rain on a scale of 100 was tested, but the forecasts were not published. In these, 100 per cent represented absolute certainty of rain, and 0 per cent, absolute certainty of fair weather. It might be mentioned here that neither 100 per cent nor 0 per cent was employed once during the six months. The results of this test were as follows:

Forecasted probability.	Number of forecasts.	Number of rains.	Actual percentage.
Per cent.			
Above 90	1	1	100
80 to 89	1	1	100
70 to 79	7	6	86
60 to 69	15	11	75
50 to 59	13	8	62
40 to 49	15	8	53
30 to 39	18	6	33
20 to 29	31	7	23
10 to 19	22	4	18
0 to 9	0	.....	.....

There were about 25 days during the six months on which no forecast was made, on account of lack of sufficient data or pressure of other work.

These results are not as satisfactory as could be desired, but it is probable that in the hands of a real forecaster the method might be of value. During the summer of 1920, these forecasts were published on the daily weather bulletin. They were supplementary to the regularly worded forecast, and were placed at the end of the summary of weather conditions. These forecasts early in the season were only for the vicinity of Roswell, but later were extended by permission to the entire agricultural district of the Pecos Valley.

It will have to be confessed that the verification during 1920 was not quite as satisfactory as in 1919. During both seasons too many "intermediate" forecasts were made; when conditions were favorable to rain the probability was usually underestimated, and was overestimated when conditions were not favorable to rain. The average verification of all forecasts of over 75 per cent was 100 per cent, and of all below 15 per cent, 0 per cent.

The basis of this style of weather forecasting is a series of composite weather maps—that is, composite so far as regards pressure, wind direction and 12-hour pressure changes. These maps originally were constructed in 1913–14, and were designed to show the frequency, in percentages, of precipitation and verifying temperature changes over the area comprising Kansas, Oklahoma,

FIG. 1A. (Solid lines, numbered 7, 8, 9, 0, 1, 2, are isobars representing "sea-level" pressures corresponding to barometer readings of 29.7 to 30.2 inches of mercury. Dashed lines indicate percentages of probability of rainfall within 36 hours after the occurrence of the type of pressure distribution indicated.

Texas, Colorado, New Mexico, Utah, and Arizona attending every type of pressure distribution that affected weather and temperature conditions in any part of that area. These composite maps were 98 in number; 62 with a LOW as the predominant pressure feature, and 38 with a HIGH predominant. A number of these have never been completed, owing to an insufficient number of available individual types. The classification was made arbitrarily, to suit the convenience of the writer, after attempts to classify types rationally had proved unsatisfactory. Classification was made according to (*a*) the location of the predominant pressure area, (*b*) its general contour and direction of major axis, (*c*) its direction of travel, and (*d*) the position of the primary opposing pressure feature; (*c*) and (*d*) often were combined. In addition, there were a number of what might be called "special cases."

* The plan of expressing the degree of assumed reliability of a forecast numerically was suggested by Freiherr von Myrbach in the *Meteorologische Zeitschrift* of October, 1913, p. 496–7, and was regularly employed by the Allied military forecasters during the late war (cf. MO. WEATHER REV., December, 1919, 47: 870).—*C. F. T.*

Five of these composite maps were presented in a published paper in 1916.[1]

Of the types represented by the 98 composite maps, no more than 30 need be considered with reference to the Pecos Valley, and of these, no more than 12 are really important. It has, therefore, been practicable to subdivide the types that concern this district without making the number unwieldy, and in a way that materially increases their value.

The three maps presented in figure 1 will serve to illustrate this subdivision. Map A is the original com-

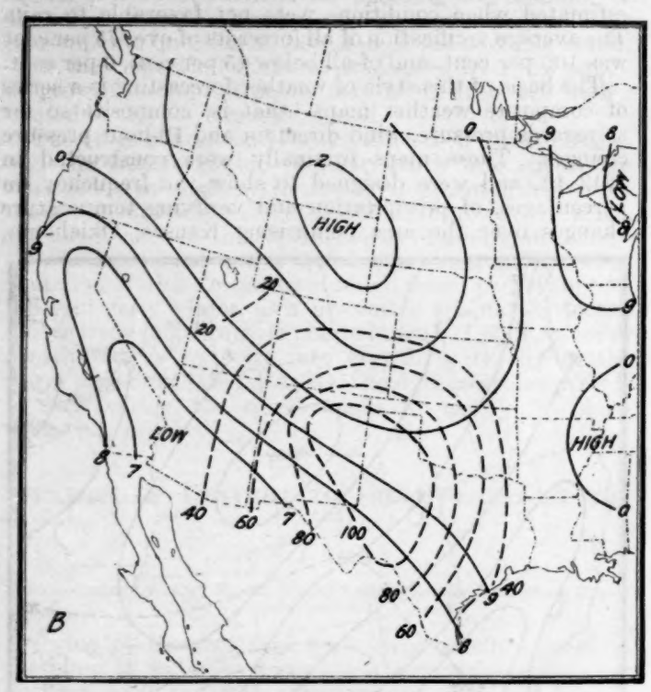


FIG. 1B. (See legend under fig. 1A.)

posite, in which the type is an elongated LOW west of the mountains, with axis northwest to southeast, with its center of depression over or south of southern Arizona, and with a HIGH to the northeast. All the individual maps used in constructing this composite conformed to these specifications. It will be seen that with this pressure distribution, precipitation occurs within 36 hours in eastern New Mexico 50 per cent of the times, and a "50 per cent forecast" is the most objectionable of all. Dividing this type, and using for map B only those cases where general precipitation occurred over eastern New Mexico and western Texas, and for map C only those where no precipitation at all occurred within that area, gives two distinct types, and it further reveals why precipitation occurs with B and not with C.

In B, the actual center of depression is much farther south than in C, a condition favorable to a direct inflow of moist air from the Gulf coast into New Mexico. In C the importation of air is from off Mexico.

Another case is presented in figure 2, where a depression is central over Arizona. Map A is a composite of a number of such LOWS that moved to the left of the normal drift (that is, northeasterly), while B is a composite of a number that moved to the right of the normal path, or southeasterly. In the one case precipitation occurs in the Pecos Valley one time in ten; in the other case nine times in ten. It often happens that when the pressure distribution is similar to that shown on map B, the LOW either remains stationary or moves southward into Mexico.

Referring again to figure 1, if map A were used the forecasted probability of precipitation would most likely be between 25 and 75 per cent. Using maps B and C the forecasted probability would be either below 25 per cent or above 75 per cent, depending upon which of the two types the current pressure distribution most nearly resembled.

Others of the original composites have been divided on a basis of the occurrence or nonoccurrence of precipitation over eastern New Mexico, which has resulted in a reduction of the number of types with which the probability of precipitation is between 25 and 75 per cent.

Improvement in this method of forecasting will result in a further reduction in the number of "intermediate" forecasts, and an increase in the number of forecasts of high and low probability. Perfection in the method would result in the use of but two values, 100 per cent and 0 per cent.

In preparing the composite maps, a base map, 7 by 5 inches, was printed on each side of standard 8.5 by 11 inch loose-leaf sheets, the map occupying the top half of the page. There were thus two maps to the sheet, one being used for charting the frequency of precipitation and the other for verifying temperature changes. The average 12-hour pressure changes and most frequent

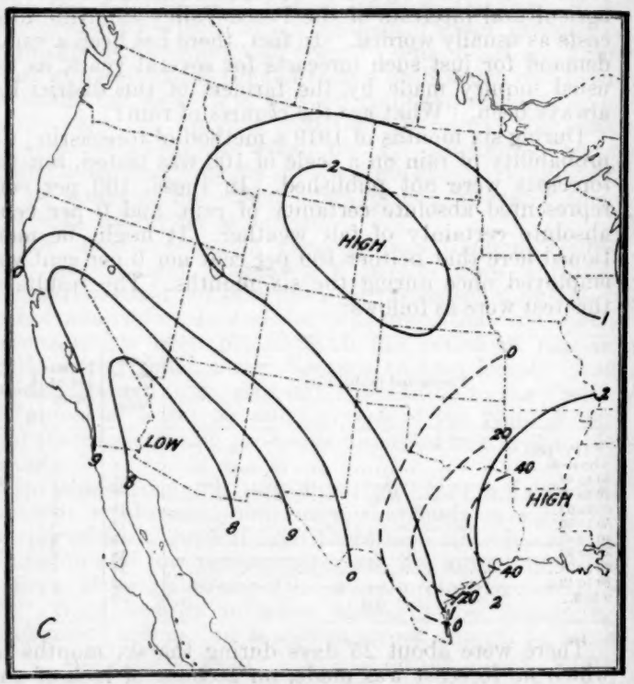


FIG. 1C. (See legend under fig. 1A.)

wind direction were also entered in cases where these are vital. The lower half of each page was reserved for typewritten notes, which, in a few cases, fill the alloted space. These notes are mostly personal observations on the results of variations from type.

In addition, a large number of individual maps have been copied and classified under the various types, and have been so cross-indexed that a LOW or HIGH appearing on any one of them can be followed from the time it first appeared within the United States until it passed east of the Mississippi.

[1] Hallenbeck, Cleve: Precipitation over the southeast Rocky Mountain slope. MO. WEATHER REV., June, 1916, 44: 341-342.

It might be mentioned here that, since each composite map was constructed with reference to the position and general contour of the predominant pressure area (or areas, in a few cases), the pressure gradient on the composite tends to "flatten out" with increasing distance from the predominant HIGH or LOW. For this reason the pressure usually was not charted east of the Mississippi.

In forecasting, these maps are used only as a basis at most, and the probability of precipitation or of verifying temperature changes, as indicated thereon, is not often accepted at its face value. General and local

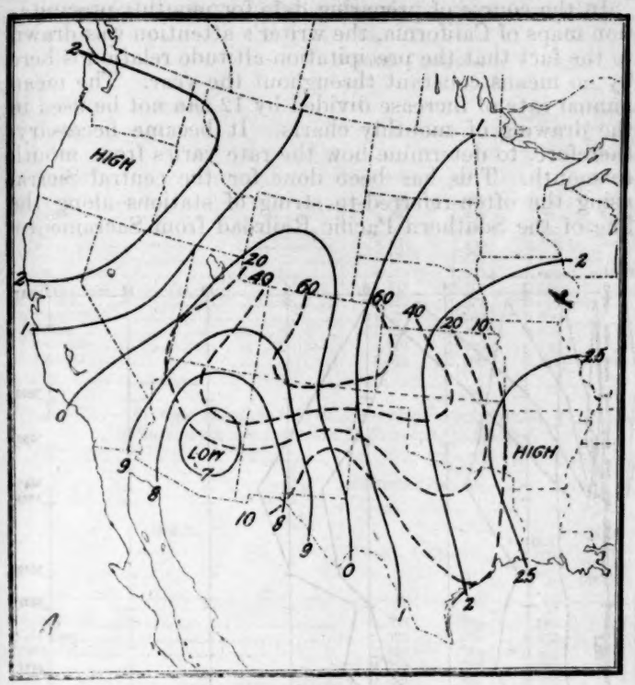


FIG. 2A. (Zee legend under fig. 1A.)

conditions usually are such as to justify modifying the indicated probability, sometimes materially; and frequently, especially in summer, the pressure distribution is so irregular, with no well-defined high or low areas, that the current weather map can not be referred to any of the classified types.

The method is no more empirical or statistical than the usual method; the principal difference is in the wording of the forecast. It requires the same careful analysis of the prevailing meteorological conditions—or as careful analysis as the fragmentary data and the limited time at the forecaster's disposal permit. It is, as has been stated by others, the forecaster's personal opinion regarding the chances of verification of a rain forecast or the nonverification of a fair weather forecast.

The use of the terms "fair," "generally fair," "possibly rain," "probably rain" and "rain" is approximately equivalent to forecasting the probability of rain on a scale of 1 to 5, and the writer employs these terms, as a rule, for precipitation probabilities of 0 to 5 per cent, 6 to 15 per cent, 16 to 30 per cent, 31 to 75 per cent, and above 75 per cent, respectively.

Precipitation forecasting for this district is seriously handicapped by the lack of weather reports from south of the latitude of Roswell. In the types of pressure distribution that are most productive of rain in the Pecos Valley, the center of the low pressure area, and frequently the major portion of the entire cyclone, is over Mexico, where its exact location and probable future movement can only be guessed.

In addition, the marked influence of the topography of this district adds another complicating factor, which makes forecasting for the comparatively level eastern half of the United States a simple problem in comparison to forecasting in the elevated and diversified districts of the western highlands.

There probably are no more than 10 days during the warmer half of the year when fair weather can be forecast for the Pecos Valley with certainty, and no more than 40 such occasions during the colder half of the year. Precipitation can not be forecast with certainty more than 6 times in the average year. This leaves at least 300 days in each year, or 5 days in 6, for which the element of doubt, in some degree, is present in the forecast.

Knowing this, the farmers of this district naturally wish to choose occasions for certain operations when the rain hazard is least. In the cutting and curing of alfalfa, most of them will accept a risk of 20 per cent—a good deal, however, depends upon the state of the crop, the press of other work, etc.

But it is in irrigation that this style of forecast is of most value. Irrigation in the Pecos Valley is done chiefly from artesian wells, each farm being an independent unit, with its individual well. The farmer can, therefore, use the water as he chooses, without having to wait for specified dates as is the case in irrigation from community canals. He can make every good rain of the summer take the place of an irrigation, and those who watch the forecasts usually suspend or postpone irrigation when the

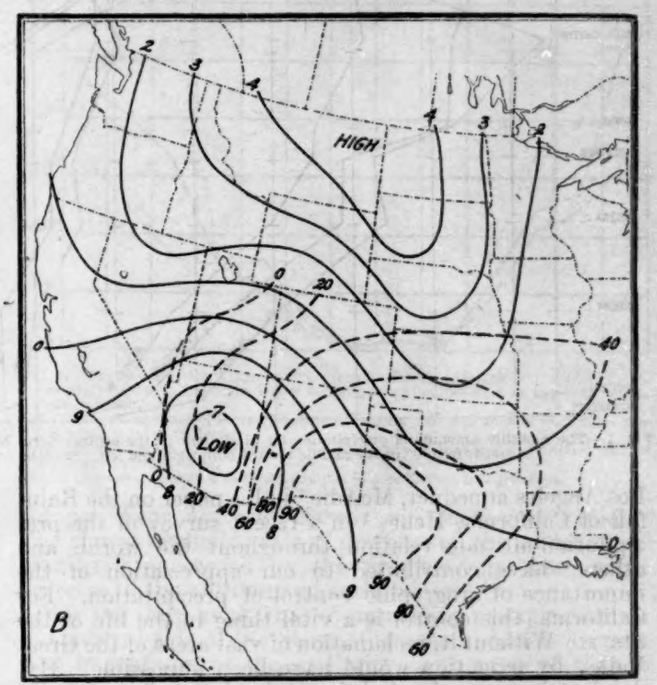


FIG. 2B. (See legend under fig. 1A.)

probability of rain is as high as 50 per cent, and often when as low as 25 per cent, provided the crops are not in immediate need of water. If the rain fails to materialize, they still have the water right at hand for irrigation. At the present time these farmers have a view only to the saving of time and labor, but the progressive extension of the farming area will within a few years reach the point where conservation of the artesian water will be necessary, and when that time arrives the precipitation forecasts for the Pecos Valley will be of more value than in any other district of equal size within the United States.

MONTHLY VARIATIONS OF THE PRECIPITATION-ALTITUDE RELATION IN THE CENTRAL SIERRA NEVADA OF CALIFORNIA.

By B. M. VARNEY.

[University of California, Oct. 19, 1920.]

SYNOPSIS.

Study of the precipitation data for a series of stations across the central Sierra Nevada of California indicates that the rate of increase of precipitation with altitude varies throughout the year in a well-defined progression from smallest rate in summer to greatest in winter. Similarly, the rates of decrease in the zone above the level of maximum precipitation, and in the zone from the summit down the leeward slope are smallest in midsummer and greatest in midwinter.

It is suggested that the observed seasonal variations are probably the result of seasonal differences in the relative humidity of the air currents involved, and that, if this be true, well marked seasonal variations in the precipitation-altitude relation may be a general characteristic of regions having pronounced wet and dry seasons.

The precipitation-altitude relation for the Sierra Nevada of California has been discussed in various connections during recent years. Lee,[1] in work for the Los Angeles aqueduct, McAdie [2] in his paper on the Rainfall of California, Henry [3] in a recent survey of the precipitation-altitude relation throughout the world, and others,[4] have contributed to our appreciation of the importance of orographic control of precipitation. For California, this control is a vital thing in the life of the State. Without it, reclamation of vast areas of the Great Valley by irrigation would have been impossible. Hydroelectric power for lighting, pumping, railway operation, manufacturing, is abundantly available (though not yet adequately developed to meet California's needs in long periods of deficient precipitation), because of the fact that precipitation increases rapidly from the west base of the Sierra up to a zone maximum amount. The annual value of this increase is about 0.9 inch per 100 feet of added elevation up to the zone of maximum at some 5,000 to 6,000 feet, above which there is a decrease toward the crest of the mountains and down on the leeward side. This zone of maximum becomes higher from north to south along the Sierra.

In the course of preparing data for monthly precipitation maps of California, the writer's attention was drawn to the fact that the precipitation-altitude relation is here by no means constant throughout the year. The mean annual rate of increase divided by 12 can not be used in the drawing of monthly charts. It became necessary, therefore, to determine how the rate varies from month to month. This has been done for the central Sierra, using the often-referred-to string of stations along the line of the Southern Pacific Railroad from Sacramento, Calif., to Reno, Nev. The facts indicated by the graphs herewith are somewhat more striking than the preliminary inspection of the data seemed to show.

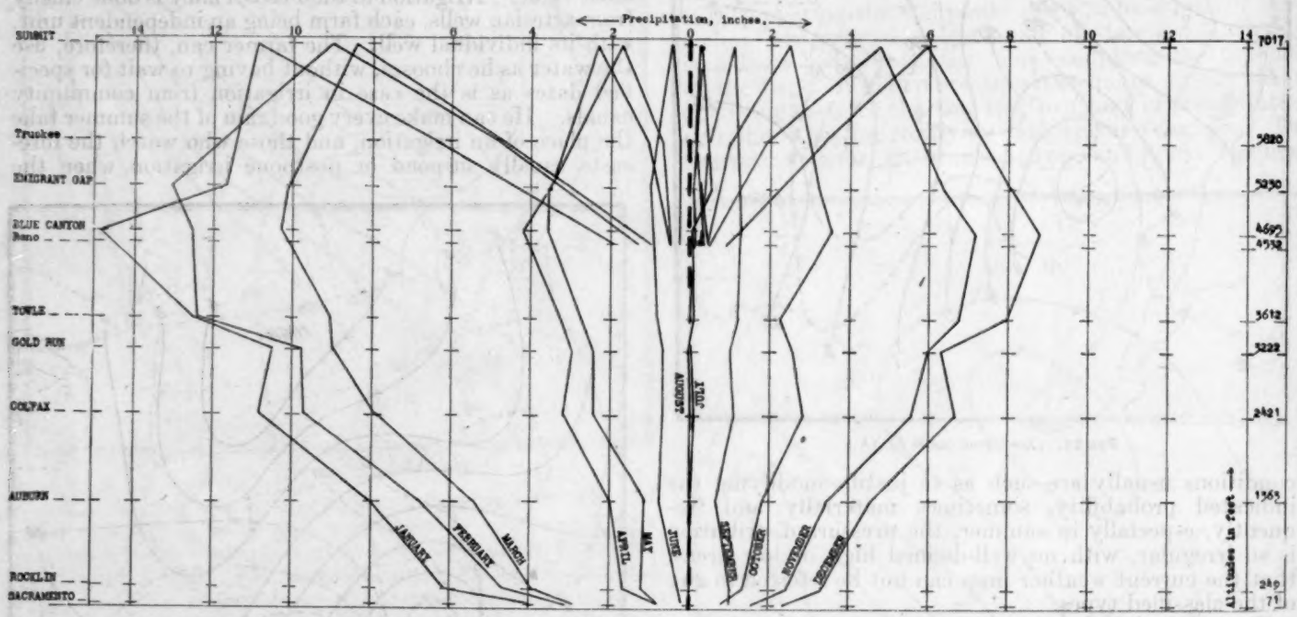


FIG. 1.—The monthly amounts of precipitation for 11 stations in the central Sierra Nevada of California. Stations arranged according to their altitudes. Precipitation scale reads from 0" in the middle toward both right and left. Stations on windward slope in capital letters, on leeward slope in small letters.

Figure 1 is a plat of the mean monthly precipitation for the 11 stations used, arranged according to their altitudes in the vertical scale. The precipitation scale runs from 0 inch in the middle of the diagram to 15 inches toward both right and left. This arrangement allows the months to appear in order across the figure and so far as possible avoids the confusion that would result from the use of a one-way scale. All stations from base to summit on the windward side of the Sierra are in capital letters, stations on the leeward side in small letters. The period on which the means are based is 20 years ending 1919. Several stations, hitherto used in discussions of the mean annual precipitation-altitude relation, have been omitted in the present study. Of these, Iowa Hill at 2,825 feet elevation on the windward side of the mountains was discontinued in 1910.

[1] Lee, C. H., MONTHLY WEATHER REVIEW, July, 1911, 39; 1099.
[2] McAdie, A., The Rainfall of California (Univ. Calif. Pub. Geog., 1914, vol. 1, pp. 127–240).
[3] Henry, A. J., Increase of Precipitation with Altitude (MONTHLY WEATHER REVIEW, 1919, vol. 47, No. 1, pp. 33–41).
[4] See paper by A. J. Henry (loc. cit.) for numerous additional references.

Cisco (5,939 feet, windward), Boca (5,531 feet, leeward), and Fernley (4,150 feet, leeward) were closed at various times during 1916 on account of faulty record. The precipitation at two stations with short periods, but very necessary in a series where the number of stations is small at best, was reduced to the 20-year period by the usual method: Rocklin, 17 years, reduced by Sacramento, and Emigrant Gap, 14 years, reduced by Blue Canyon.

TABLE 1a.—*Average monthly rates of increase of precipitation with altitude, from windward base station to level of maximum precipitation.*

Month.	Altitude difference.		Rate.	
	Feet.	Meters.	Inches per 100 feet.	Millimeters per 100 meters.
January	4,624	1,409	0.232	19.3
February	4,624	1,409	0.201	16.7
March	4,624	1,409	0.161	13.4
April	4,624	1,409	0.074	6.1
May	5,159	1,572	0.055	4.6
June	5,159	1,572	0.014	1.2
July	6,946	2,117	0.004	0.3
August	5,159	1,572	0.010	0.9
September	4,624	1,409	0.005	0.4
October	4,624	1,409	0.058	4.8
November	4,624	1,409	0.120	10.0
December	4,624	1,409	0.134	11.4

TABLE 1b.—*Average monthly rate of decrease of precipitation, from level of maximum precipitation to Summit, windward.*

Month.	Altitude difference.		Rate.	
	Feet.	Meters.	Inches per 100 feet.	Millimeters per 100 meters.
January	2,322	708	0.168	14.0
February	2,322	708	0.153	12.7
March	2,322	708	0.079	6.5
April	2,322	708	0.075	6.2
May	2,322	708	0.079	6.5
June	1,718	545	0.023	5.4
July	0	0	0	0
August	1,787	545	0.019	1.6
September	2,322	708	0.008	0.7
October	2,322	708	0.048	3.9
November	2,322	708	0.104	8.6
December	2,322	708	0.122	13.7

TABLE 1c.—*Average monthly rate of decrease of precipitation, from Summit to base station, leeward.*

Month.	Altitude difference.		Rate.	
	Feet.	Meters.	Inches per 100 feet.	Millimeters per 100 meters.
January	2,485	757	0.363	30.3
February	2,485	757	0.312	25.8
March	2,485	757	0.302	25.1
April	2,485	757	0.075	6.2
May	2,485	757	0.050	4.2
June	2,485	757	0.010	0.8
July	2,485	757	[1] 0.006	0.5
August	2,485	757	[1] 0.006	0.5
September	2,485	757	0.031	2.6
October	2,485	757	0.082	7.0
November	2,485	757	0.170	14.1
December	2,485	757	0.196	16.4

[1] Increase.

A study of the figures and the table emphasizes several facts, which may be stated with reference to the three zones of precipitation indicated: First, the zone from the base station up to the approximate average level of maximum precipitation on the windward slope, Blue Canyon, at 4,620 feet, being the station nearest to the actual level of the maximum for most months; second, the zone between the level of the maximum and the highest station of the series (Summit, at the crest along the line of the railroad); third, the zone from Summit down the leeward slope of the Sierra to Reno.

For the first zone it is evident that a mean of all the monthly values of the precipitation-altitude relation is not even approximately that of a given month. In place of monthly values oscillating but slightly on either side of a mean, there is a gradual though somewhat irregular progression from the maximum rate of increase in the midwinter to the minimum rate in midsummer, followed by an increase toward the succeeding midwinter. Or, in terms of the seasonal subtropical régime of precipitation, which largely influences most of the important activities of California, the rate is least in the dry season and greatest in the middle of the rainy, with all gradations between.

For the second zone, the windward zone of decreasing precipitation, the same sort of relation holds. The rate of decrease, at its maximum in January, declines slowly

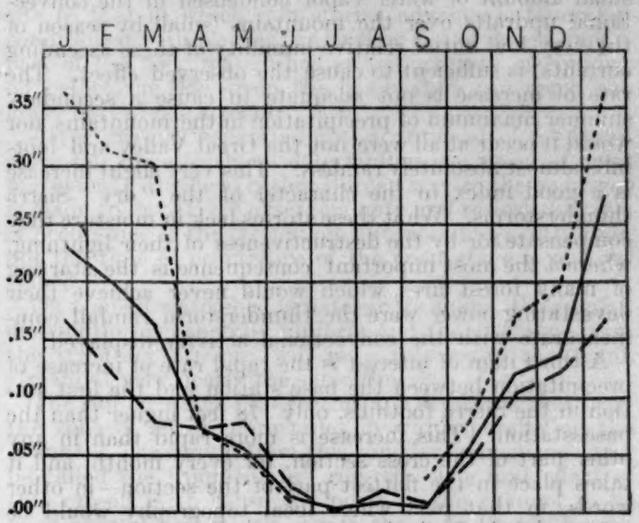


FIG. 2.—The monthly variations of the precipitation-altitude relation, central Sierra Nevada of California, in hundredths of an inch change per 100 feet difference of elevation. Data from table 1.
Solid line—average rate of increase between base stations and zone of maximum precipitation, windward slope.
Broken line—average rate of decrease between zone of maximum precipitation and summit, windward slope.
Dotted line—average rate of decrease, summit to base station, leeward slope.

through February and March, and then very rapidly. The almost negligible rate of decrease of the midsummer months is succeeded by the progressively more rapid decrease of the autumn and early winter.

For the third zone, that of decreasing precipitation on the leeward side of the Sierra, the general fact is evident that in addition to the similarity as to rates of change through the year as compared to the other zones, the rate for most months is much greater than in the zone of decrease on the windward side.

Reference to figure 2, in which are shown the average monthly rates of change for the three zones, in hundredths of an inch of precipitation per 100 feet of change in elevation, as set out in the table, will make the above facts clearer. Only April to June, inclusive, and September-October, show essentially the same rate of change for all three zones. The zone of increase (solid line) shows a rate of change that is, broadly speaking, midway between the rates in the windward and leeward zones of decrease.

Further details of the relations between the rates in the different zones are obvious from the figure.

A number of other points in connection with figure 2 may be mentioned. The break in the dotted line for the leeward decrease zone is made necessary by the fact that for July and August the decrease with lessening altitude is replaced by an increase, when the whole zone from Summit to Reno is considered. Decrease holds at least as far down the leeward slope as Truckee (1,179 feet below the summit), but at Truckee or beyond, an increase begins, in spite of the fact that Reno has, like all the other stations in this series, a pronounced midwinter maximum of precipitation. Reno has also, however, a slight midsummer secondary maximum, the rainfall of which, though small in amount, is not as scanty as the summer rains of higher altitudes.

A second point of interest concerns the high altitude rains just mentioned. They are thunderstorm rains, and they cause a slight increase in the rates of change of precipitation with altitude in August, in the midst of a season otherwise characterized by rates of change so small as to practically negligible. Cyclonic control of precipitation is at a minimum in this season, so that even the small amount of water vapor condensed in the convectional updrafts over the mountains (small by reason of the very low initial relative humidity of these ascending currents) is sufficient to cause the observed effect. The rate of increase is not adequate to cause a secondary summer maximum of precipitation in the mountains, nor would it occur at all were not the Great Valley and foothills almost absolutely rainless. This very slight increase is a good index to the character of the "dry" Sierra thunderstorms. What these storms lack in moisture they compensate for by the destructiveness of their lightning, whereof the most important consequence is the starting of many forest fires, which would never achieve their devastating power were the thunderstorm rainfall commensurate with the convectional activity displayed.

A third item of interest is the rapid rate of increase of precipitation between the base station and the first station in the Sierra foothills, only 178 feet higher than the base station. This increase is more rapid than in any other part of the cross section, for every month, and it takes place in the flattest part of the section—in other words, in that part where local topography would be expected to have the least influence. This suggests that it is probably due to the growth westward, of the thickened cyclonic cloud mass over the mountains and foothills, thus extending the influence of the Sierra as a rain maker some little distance out over the Great Valley. This thickening and westward growth is probably due to the action of the air currents under either one or both of the following conditions: It is conceivable that even in the very obtuse angle formed by the almost dead-level surface of the valley and the sloping surface of the Sierra a retarding and banking up of air may occur (similar to that observable in an air current on the windward side of a high fence), probably aided by friction over the increasingly rough country of the foothills. Or, a similar banking up may be induced by the obstruction offered to the general flow of air by increased convection resulting from the more rapid condensation at higher altitudes over the mountains. In either case the upward slope of the overpassing air currents would not begin over the foothills but to the west of them, with consequent increased precipitation in the valley as observed.

The cause of the great seasonal fluctuation in the rates of change is an important item. It can not lie in monthly variations in the numbers of cyclones crossing the area, because in a given month that is the same for both mountains and valley. It probably lies in the higher initial relative humidity of the moisture-bearing cyclonic winds (S., SE., SW.) from the Great Valley in the winter as compared to the summer. This seasonal difference in relative humidity is very great. Sacramento at 5 p. m. (local time) in January has a mean relative humidity of 75 per cent, in July of 36 per cent. For Fresno, further south, and not under the influence of the damp winds flowing through the break in the coast ranges at San Francisco Bay, the percentages are 70 and 14, respectively. Another factor that may have some influence in producing more condensation in winter is the snow cover in the mountains. It might seem that this should be a very important factor, but temperature differences between the valley and the zone of maximum in January and July suggest that it is not. The difference between the mean temperatures at Sacramento and Blue Canyon in January is 8 degrees F., and in July is 8.4 degrees F.

The question arises as to whether the strong seasonal swing of the precipitation-altitude relation here described may not be a characteristic of many regions having marked seasonal types of rainfall. If relative humidity is the controlling factor, it would seem that this character should hold for any region where, in addition to the systematic advance and retreat of a belt of rains, the intervening dry seasons bring on sharp contrasts in the relative moisture content of the air.

Finally, the changes in the elevation at which the maximum precipitation occurs is of interest. The generally accepted view that this level is higher in summer and lower in winter, with gradations between, seems, for the central Sierra at least, to be true only in part. Blue Canyon at 4,695 feet is the station nearest the level of maximum from September to April with the exception of February. Pronounced upward tendency begins in May, when Emigrant Gap at 5,230 feet and Blue Canyon have the same rainfall. The level rises to its greatest height (Summit, 7,017 feet) in July, after which it declines again to Blue Canyon by September. For the major part of the precipitation season, there is, so far as our sparse data show, no change except a contrary one in February, up instead of down. Nevertheless, judging from the trend of relative humidity values in the valley (pronounced midwinter maximum, summer minimum) the level should decline consistently toward the middle of the season and rise thereafter. It could descend some 540 feet below Blue Canyon before appearing as a maximum in the data for the next station below, at 3,612 feet. At the best, then, any lowering of the level there may be during the months whose precipitation counts most, is small compared to the rise in the summer months. The scarcity of stations makes it impossible to determine with any approach to accuracy what the real behavior of the level is during the greater part of the rainfall season.

FLOOD CRESTS ON THE OHIO AND MISSISSIPPI, AND THEIR MOVEMENT.

By ALFRED J. HENRY, Meteorologist.

SYNOPSIS.

This study is based on the results of daily gagings of the Ohio and Mississippi Rivers under the varying conditions of stream flow that may arise in the course of a year.

The actual velocity of flood flow for a number of freshets and flood flows have also been considered.

Owing to the difficulty in evaluating the influence of some of the important factors that determine the velocity of flow of water in open channels, no simple formula of general application has yet been developed.

While the velocity of flow of water in an open channel is greater the higher the stage and is greater in a rising than in a falling river, yet the movement of crest stages—not being dependent wholly upon the velocity of flow—appears to be more rapid at comparatively low stages when the water is well within the banks of the stream than when the banks are overtopped as at very high stages. The reasons are fairly obvious although local conditions and the tributary effect may be the dominating influence as at Cairo, Ill., where, at times, the balance between inflow and outflow is disturbed by the channel capacity below Cairo. Overflow of lowlands on the left bank opposite and immediately below Cairo at stages above 40 feet results in more or less retardation in the velocity of the outflow and crest stages on the Cairo gage may be due to that cause alone.

The average rate of flood flow in the upper Ohio is about 5 miles per hour and on the Mississippi below Cairo very close to 4 miles per hour, although crest stages move at a slower rate.

In the practical work of forecasting the date of occurrence of flood crests it becomes important to have a clear understanding of the conditions which precede and attend the rise of a flood and its subsequent movement down stream.

The flow of water in open channels.—The flow of water in natural and artificial channels has been under observation for more than a century and much time and energy has been expended in the development of a formula which shall truly represent the mean velocity of a stream. The basic formula for the velocity of water as an element in estimating the discharge of a stream is that of Chezy (1775).

$$v = c\sqrt{r\ s}, \text{ in which}$$

v is the mean velocity in feet per second; c a coefficient combining the total effects of the roughness of the bed and all other conditions which may effect the velocity except the two remaining terms (r) hydraulic radius and (s) slope. Ganguillet and Kutter[1] (1869) succeeded in expressing the coefficient c in terms of r, s, and n in which r and s have the same significance as in the Chezy formula and n is a separate factor to indicate roughness, and should be estimated upon data collected in the field.

The equation as developed by Kutter is complicated and for obvious reasons its application to conditions of flood flow is exceedingly difficult. The movement of a flood down the stream channel can be determined with considerable accuracy by gage readings especially when the range from low to high water is great and tributary effects are absent. The simplest case is that of the sudden release of a large body of water as by the failure of a dam. The rapidity of movement of the resulting flood wave downstream will depend largely upon the general water level at the time of the failure of the dam. If at a very low stage the speed of the flood wave will be much retarded both on account of greater friction upon the bed and sides of the channel and because of the time consumed by the flood waters in filling the pools and low places in the channel and also in overflowing the low spots in the flood plain. With the water at a moderate stage the flood flow will be more rapid and will closely approximate that of a moderate flood produced by natural causes.

The most important factors affecting the flood flow of a stream are the size and shape of the watershed and its geographic position with respect to the prevailing direction of rain storms which pass over it. The larger the watershed the less the likelihood of torrential rains falling over its entire area and therefore the less the probability of a severe flood. Even though torrential rains should fall over one or more of the smaller tributaries of the watershed the resulting flood wave will flatten out when it reaches the main stream.

A drainage area so shaped that the discharge from its tributaries will reach the trunk stream at about the same time will promote the occurrence of maximum floods. A watershed in which the drainage is in a direction opposite to that in which rain storms advance is favorably conditioned with respect to the slow rise of floods since a part of the flood waters has an opportunity of running off before the flow from the headwaters can reach the lower part of the stream.

River gagings separated by an interval of 24 hours serve but imperfectly in determining the speed of crest movement. In the Weather Bureau service the endeavor is made to have river observers note and record the time of occurrence of the crest stage but more frequently than not the time of occurrence of the crest stage is not obtained.

On a small watershed, whatever its shape, the rainfall distribution is generally uniform and the discharge from the tributary streams will as a rule reach the trunk stream at very nearly the same time.

The run-off which first reaches the stream is that from the zone of 50 or more miles in width paralleling the channel. The run-off from this zone for convenience may be called the "immediate" run-off. The first effect of this run-off is to cause the pools in the channel to be filled up and naturally a rise in the river that is practically simultaneous throughout its entire length. As the run-off from the more remote parts of the watershed reach the trunk stream a definite crest stage which may be a few inches or a few feet in magnitude is reached at and immediately below the junction of the upper main tributary streams with the trunk stream. Whether the crest will increase in magnitude or flatten out as it passes downstream is conditioned almost wholly upon the run-off of the tributaries that join the trunk stream in its lower reaches. It may happen that the run-off of the lower tributaries has reached the trunk stream in sufficient volume to cause a definite crest stage before the the arrival of upstream water and that the arrival of this water merely tends to retard the fall and thus prolong the flood wave. In all such cases the movement of the upstream crest can not be followed. Again it may also happen that after a rainy period of several days duration the rains in the upper part of a watershed may be sufficient to start a moderate flood wave downstream. This flood wave advancing successively into stretches of a rising stream moves with a speed closely approximating that of the maximum of flowing water in a stream.

An example of a flood wave that apparently passed from Warren, Pa., to New Orleans, La., in 19 days, or at

[1] Ganguillet & Kutter, The Flow of Water in Rivers and Other Channels, English Translation, 1889.

the rate of about 100 miles per day, is afforded by the freshet of October-November, 1917. This freshet occurred at a time when all streams were at a low stage; it was caused by short period of almost daily moderate showers in the watersheds of the northern tributaries of the Ohio extending from Indiana to western Pennsylvania and was followed by about three weeks of rainless weather thus giving an opportunity to follow the rise downstream without the usual complications which arise from the tributary effect due to rains after the crest has been reached. On examining the record more closely it was found that there were at least two distinct crests separated by about a week and that the second crest overtook the first at Cincinnati, Ohio, about October 30; thereafter, while the progress of the first wave can be shown by the daily rise there was a steady and more or less continuous rise to the principal crest a few days later.

Below Baton Rouge the indications as to the date of the crest are uncertain, but it probably occurred at New Orleans on the 19th.

The details of the progress of both crests are shown in the subjoined table, and the advance of the rise on the Mississippi, Cairo to New Orleans, is illustrated in figure 1.

River and station.	First rise.				Second rise.				
	Date, 1917.	Stage feet.		24-hour rise.	Date.	Stage feet.		24-hour rise.	Above Cairo (miles).
		From—	To—			From—	To—		
Allegheny.									
Warren, Pa	Oct. 20	0.7	4.2	3.5	Oct. 30	9.7	12.8	3.1	1,144
Franklin, Pa	...do	2.1	4.5	2.4	Oct. 31	9.4	12.4	3.0	1,081
Parkers, Pa	...do	2.0	4.3	2.3	...do	12.8	14.7	1.9	1,040
Freeport, Pa	...do	4.1	10.0	5.9	...do	15.9	19.1	3.1	996
Ohio.									
Pittsburgh, Pa	Oct. 20	6.0	6.5	0.5	Oct. 31	11.9	14.4	2.5	967
Wheeling, W. Va	...do	3.3	10.0	6.7	Nov. 1	21.1	21.6	0.5	879
Parkersburg, W. Va	Oct. 21	11.0	12.7	1.7	Nov. 2	22.0	22.1	0.1	784
Point Pleasant, W. Va	Oct. 20	7.1	11.3	4.2	...do	22.7	24.0	1.3	703
Huntington, W. Va	...do	7.5	12.3	4.8	...do	24.0	25.0	1.0	657
Portsmouth, Ohio	...do	4.8	14.0	9.2	Nov. 3	27.4	28.2	0.8	612
Cincinnati, Ohio	Oct. 22	[1] 12.5	15.5	3 3	Nov. 4	27.5	28.0	0.5	499
Madison, Ind	...do	9.3	11.9	2.6	Nov. 5	22.7	23.0	0.3	412
Louisville, Ky	Oct. 23	9.1	9.3	0.2	...do	10.4	10.5	0.1	367
Cloverport, Ky	Oct. 25	8.8	11.0	2.2	Nov. 6	20.3	20.6	0.3	260
Evansville, Ind	Oct. 26	8.5	11.4	2.9	Nov. 7	20.2	20.5	0.3	181
Shawneetown, Ill	...do	5.4	9.0	3.6	...do	19.6	19.8	0.2	119
Paducah, Ky	Oct. 27	4.2	6.2	2.0	Nov. 8	14.4	14.5	0.1	43
Cairo, Ill	Oct. 28	9.6	11.5	1.9	Nov. 9	19.1	19.2	0.1	.....
Mississippi.									*Below Cairo.*
New Madrid, Mo	Oct. 29	8.1	9.0	0.9	Nov. 9	13.8	14.0	0.2	71
Memphis, Tenn	Oct. 31	5.6	7.2	1.6	Nov. 12	12.3	12.6	0.3	227
Helena, Ark	Nov. 1	5.2	6.6	1.4	...do	13.9	14.2	0.3	307
Arkansas City, Ark	Nov. 2	6.4	7.7	1.3	Nov. 14	16.2	16.5	0.3	437
Greenville, Miss	Nov. 3	5.8	6.8	1.0	...do	11.3	11.6	0.3	480
Vicksburg, Miss	Nov. 4	4.3	5.3	1.0	Nov. 16	12.5	12.6	0.1	602
Natchez, Miss	Nov. 5	6.0	6.9	0.9	Nov. 17	13.7	13.8	0.1	706
Baton Rouge, La	Nov. 7	3.2	3.7	0.5	Nov. 18	7.0	7.3	0.3	841
New Orleans, La.[2]	.....	.....	.....	.....	.....	.....	.....	.....	964

[1] Pool stage.

[2] Crest dates uncertain, probably second on Nov. 19.

Attention is directed to the fact the the first or preliminary crest was reached on the Ohio from Portsmouth almost to the headwaters of the Allegheny in northern Pennsylvania on October 20, excepting only a short stretch of the river between Marietta, Ohio, and Parkersburg, W. Va., where the discharge from the Muskingum came out a day later. This rise in the streams from a low stage was due to very general rains on the 19th over the entire basin. There was no pronounced flood peak at any point along the river, although the discharge of the tributary streams which enter the Ohio on the right bank between Pittsburgh, Pa., and Cincinnati, Ohio, was sufficient to create a distinct rise in the river which can be traced more or less definitely from the headwaters to New Orleans, La.

The column in the table headed "24-hour rise" shows roughly the volume of flood flow that passed the respective gaging stations. The relation between gage heights and discharge for the stations in the table is of course not a fixed one nor are the gage heights at the several stations strictly comparable among themselves, although the gaging stations on the Ohio above Cincinnati are fairly comparable. The river at Madison, Ind., and below is considerably wider than at points upstream. This is especially true for Louisville, Ky., where the river at bankful stage is 3,400 feet wide, almost twice as wide as at Cincinnati. The gage relations between the two stations vary within very wide limits. At extremely low stages a rise of a few feet at Cincinnati may not show on the Louisville gage and, on the other hand, at a 50-foot stage on the Cincinnati gage, and a corresponding high river below 75 per cent of the rise at Cincinnati will show on the Louisville gage.

The weather after October 20 was showery with rains almost daily in some part of the basin, so that the streams rose quite generally.

On the 30th a general and moderately heave rain occurred over the upper Ohio basin, producing the rises shown in the table under the caption "Second rise."

The speed of the first rise computed from crest stages, Cincinnati to Cairo, was approximately 3.4 miles per hour, and from Cairo to Baton Rouge, La., 3.5 miles per hour.

The bulk of the run-off from the rains of October 30 appears to have reached the Allegheny throughout its entire length on the 30th–31st, October. Although the crest stages on that stream occurred some time after 8 a. m. of the 31st. The crest at Pittsburgh was reached at 11 a. m. on that date and by the next morning the river was falling throughout its entire length. The crest at Wheeling, 87 miles below Pittsburgh, was reached in 13 hours, or at the rate of 6.7 miles per hour. The crest at Parkersburg, 95 miles below Wheeling, was reached in

23 hours, or at the rate of but 4.1 miles per hour. No definite times of the occurrence of the crest were reported below Parkersburg and we must therefore assume that the 8 a. m. readings correspond to the crest stages at points on the lower river. The velocity thus computed is 4.4 miles per hour.

From Cairo to Baton Rouge the velocity was about 4 miles per hour as compared with 3.5 miles for the first rise; it should be remembered, however, that in reality the second rise merged almost imperceptibly into the first from below Cincinnati to Natchez which doubtless accounts for the rapidity of movement.

Instead of using gage heights in determining the time of occurrence of the crest stage we may consider the time interval between successive rises of some definite magnitude, say 1 or 2 feet between stations located at varying distances below the headwater stations. When, for example, a river is falling or stationary an increase in gage height can be interpreted in but one way, viz, as showing an increase in streamflow, channel conditions remaining the same. The increase in streamflow first noticed at a gaging station is generally the result of what has been hereinbefore called the "immediate" run-off but when the rise is pronounced we may note the time required for a rise of similar magnitude to reach the gaging station next below. The 24-hour rises in the Mississippi from Chester, Ill. (115 miles above Cairo, Ill.), to New Orleans, La., for the period during which the two freshets hereinbefore described passed down stream have been plotted to form figure 1 below.

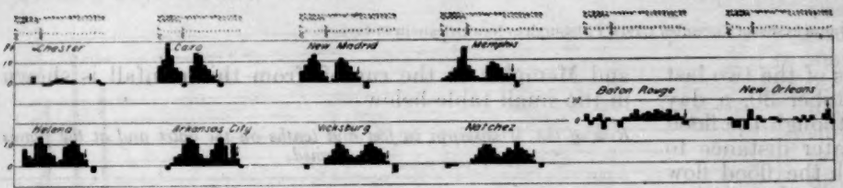


FIG. 1.—Autumn freshets out of Ohio merging into a single crest in lower Mississippi, October–November, 1917.

This diagram, first of all, shows that the rise came almost wholly from the Ohio. A simple inspection shows, moreover, that the rise progressed downstream at a fairly uniform rate. The first rise of 1 foot or more on the Cairo gage occurred on October 27. Considering that date as the date of origin it may be seen that a rise of as much as 1 foot was seven days in reaching Vicksburg, Miss., or at the rate of 3.6 miles per hour, practically the same as found by a consideration of crest stages in a preceding paragraph. The second rise on the Cairo gage was not so great as the first and was separated therefrom by a period of but 24 hours during which time the river remained stationary at 13.8 feet—a stage about 5 feet higher than when the initial rise began on October 26. This second rise, as may be seen from the diagram, progressed downstream a little more rapidly than the first. Considering the rise of 0.8 foot at Cairo on November 3 as the reference datum the progress of the rise downstream is shown in the small table below.

Station.	Initial rise.	Date.	Maximum rise.	Date.
Cairo, Ill	0.8	Nov. 3	1.4	Nov. 4
New Madrid, Miss	0.9	Nov. 4	1.1	Nov. 5
Memphis, Tenn	0.7	Nov. 6	0.9	Nov. 7
Helena, Ark	0.9	Nov. 7	1.2	Nov. 9
Arkansas City, Ark	0.7	Nov. 8	1.3	Nov. 10
Vicksburg, Miss	0.6	Nov. 10	1.0	Nov. 12
Natchez, Miss	0.7	Nov. 11	1.0	Nov. 13
Baton Rouge, La	0.5	Nov. 12	0.5	Nov. 15

The distance from Cairo to Baton Rouge, 841 miles, was covered in 9 days, or at the rate of 3.9 miles per hour. The slight difference in speed between the first and second rise may be accounted for by the fact that the river stood a little higher at the beginning of the second rise than at the beginning of the first.

MEASURED VELOCITIES OF STREAM FLOW.

Since the velocity of flow is an important factor in the determination of discharge, many careful and accurate measurements of the actual velocity of flow are available. The early observations by Humphreys and Abbot on the Mississippi, as well as the later observations by the Mississippi River Commission, have been considered. A casual inspection of these observations shows at once that the velocity is greater for rising than for falling stages and that owing to wind action and possibly other local influences different velocities are sometimes indicated within comparatively short sections of the river. Discharge observations made at Columbus, Ky., for stages of 40 feet and above with a rising river give an average velocity of 5.3 miles per hour. For approximately the same stage, but for a falling river, the average velocity was found to have been 4.6 miles per hour. At stages of about 30 feet the observations are not so numerous as at 40 feet, but the excess in the velocity of flow for a rising river appears to be greater than at the stage of 40 feet.

Observations at Vicksburg, Miss., for stages between 40 and 45 feet and a rising river give an average velocity of 4.6 miles per hour and for a falling river at the same stages 4.3 miles per hour.

Observations in the Mississippi River above Carrollton, La., during the flood of 1912 and 1913 give average velocities in the main channel of 4.1 and 3.9 miles per hour, respectively, for the two floods. These observations were made on a rising river.

The engineers of the Miami conservancy district carefully computed the maximum discharge rates in the Great Miami and tributaries during the flood of 1913.[2]

The computed velocities at the time of maximum discharge depend very considerably upon slope. They ranged from a maximum of 2.7 miles per hour at a slope of 0.29 foot in 1,000 to an individual maximum of 10 miles per hour at a slope of 3.5 feet in 1,000.

Maximum velocities greater than 6.5 miles per hour were very rarely observed in the Mississippi.

In general, the maximum velocity of flowing water in the lower Mississippi during high water is close to and probably slightly in excess of 4 miles per hour. It is probable that maximum velocities as great as 4.5 miles per hour may be experienced in the front of the flood wave, but since the flood front is naturally of limited extent an average value of 4.5 miles is considered too high.

The average interval between flood crests, Cairo to Memphis, as empirically determined is about 5 days with a possible variation of as much as 40 per cent. The interval is nearly always greater for high water—a stage of 50 feet or over on the Cairo gage—than for low water. For Cairo stages between 20 and 40 feet the average interval is very close to 3 days, which corresponds to a speed of 3.1 miles per hour for the most rapid moving crests. The great flood crests appear to move on the average with

[2] Miami Conservancy District. Technical Reports, Part IV, Table No. 3, Ivan E Houck.

a speed of 1.9 miles per hour. The average interval for great flood crests between Cairo and Vicksburg is about 16 days with a possible variation of 3 or 4 days on either side. This corresponds to a speed of about 1.5 miles per hour.

A further example of rapid crest movement is that afforded by the

AUTUMN FRESHET OF 1918.

This freshet had its origin in the rains of October 30, 31, in the Ohio watershed, mostly over the southern tributaries. Its beginning was not clearly marked, but it may be said to have passed from Pittsburgh, Pa., to New Orleans, La., in about 22 days, increasing in magnitude as it passed downstream, the increase being due to a fortunate combination of the tributary freshet flow with that of the main stream. The tributaries concerned were the Kanawha, the Big Sandy, the Kentucky, and the Tennessee and Cumberland, all southern tributaries. It so happened that the rainfall on the headwaters of the two last mentioned was unusually heavy on October 30, a day sooner than on other tributaries, and, although the flood waters of both these streams had a greater distance to cover, they synchronized fairly well with the flood flow coming down the Ohio. Thus it happened that with a total rise of but 3.6 feet at Pittsburgh to a stage of 9.9 feet on November 1, the total rise at Cairo had increased to 12.5 feet and the stage reached was 23.2 feet. This rise was sufficient to carry through to New Orleans in about 14 days and to Vicksburg in 8 days, the latter being one among the most rapid movements ever experienced. The progress of this freshet is graphically shown in figure 2. An analysis of this illustration discloses the following: The rise in the Ohio at Pittsburgh and Wheeling had diminished to about one-third of its volume as measured by gage heights when it reached Parkersburg. A sharp rise in the southern tributaries below Parkersburg reaching the trunk stream 24 hours before the up-river water had arrived, advanced the date of the crest between Point Pleasant and Cairo by that amount. At Cincinnati and Madison the river rose about a foot on October 31, evidently due to the same rainstorm that caused the rise at Pittsburgh and Wheeling a day later. This rise can be definitely traced to Cairo, but appears to have lost its identity at New Madrid, although it reappears at Arkansas City and below; hence we have, as before, a series of rather small rises progressing downstream and separated from each other by a very short time-interval. This condition appears to be conducive to the maximum rate of flow.

Still another example of the movement of flood crests at initially low stages is afforded by the freshet in the lower Ohio and the Mississippi below Cairo produced by the exceptionally heavy rains that fell within 60 hours over southwestern Ohio, southern Indiana and Illinois, and western Kentucky, October 3–6, 1910. Over this region the rainfall was nowhere less than 6 inches and in localities as much as 15 inches. The streams were low and the ground was dry, hence a damaging flood did not result. The heavy rainfall was confined to the regions above named and there was no pronounced rise in the Ohio above Cincinnati. At that place the river rose 10.6 feet in 48 hours; at Evansville the total rise was 21.1 feet in 7 days and at Cairo 14.6 feet to a stage of 26.8 feet in the same time. This rise was sufficient to carry through to New Orleans although the date of arrival at that place is more or less uncertain. The rate of movement from Cairo to Memphis was 4.7 miles per hour; Memphis to Vicksburg, 3.1 miles per hour. It is probable that the high velocity, Cairo to Memphis, was due in a measure to the heavy rain that fell directly into the channel and over the area between the levees. The total rainfall at Memphis, October 3–6, was 4.73 inches; Cairo, 10.92 inches, and, of course, proportionate amounts between these two points. The response of the river at Cairo and Memphis to the run-off from this rainfall is shown in the small table below.

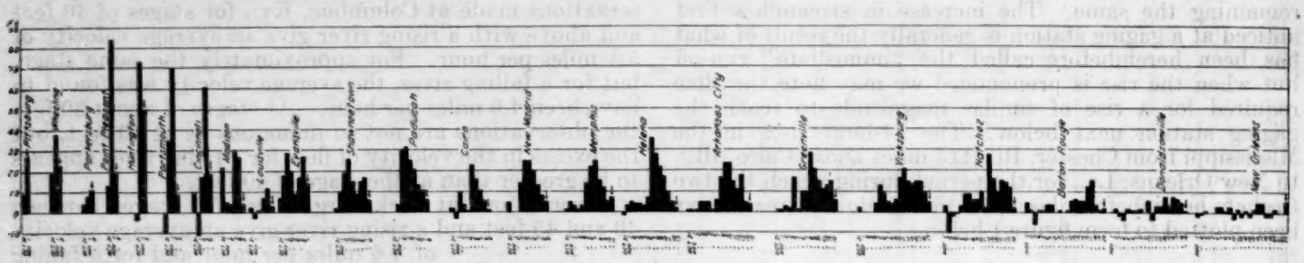


FIG. 2.—The autumn freshet of November 1, 1918, Pittsburgh to New Orleans in 23 days.

Rise of the Mississippi in feet and tenths on the dates and at the places named.

Date.	Cairo.	Memphis.
Oct. 5	0.9	0.1
Oct. 6	3.9	0.7
Oct. 7	4.0	0.6
Oct. 8	1.6	2.0
Oct. 9	2.3	2.7
Oct. 10	1.6	2.1
Oct. 11	0.3	1.7
Oct. 12	.....	1.2
Oct. 13	.....	0.6

These figures show that the main rise which began at Cairo on the 6th appeared two days later at Memphis. Up-river water at Cairo did not arrive until the 9th and it was doubtless due to that fact that the crest both at Cairo and Memphis was reached on the 11th and 13th, respectively. Figure 3 illustrates the progress of this freshet.

I pass now to a consideration of the movement of a well-defined flood on the Ohio due to rain and melting snow. The flood selected is that of January 8–26, 1913. This flood had its origin in a few days of relatively high temperature with rain over practically the whole of the Ohio basin. The high temperature caused much snow water to reach the trunk stream and the subsequent weather was favorable to continued high run-off until near the close of the month. The distribution of the run-off from melting snow is different from that of rainfall in that while a rainstorm generally passes across the entire watershed in 24 hours and the run-off therefrom ceases shortly after the end of the rain, the discharge from melting snow continues uninterruptedly so long as the temperature remains substantially above freezing. In

the case under consideration the temperature was considerably above freezing for upwards of 70 hours and longer over the southern tributaries. As a result the Ohio from Pittsburgh to Cairo rose continuously and rather uniformly for several days; the average rise on the 8th was 7.6 feet, on the 9th 7.6 feet, on the 10th 4.3 feet, on the 11th 2.7 feet, on the 12th 3.8 feet, and on the 13th 2.4 feet.

When a stream is rising from its source to its mouth there can be no real pronounced crest except as some tributary contributes an unusually large volume of water. In this case the run-off from melting snow in the Allegheny and other rivers that converge at Pittsburgh was checked on the 9th and the flood crested at Pittsburgh on that date. The crest was reached at Wheeling 86 miles downstream on the 10th, but the river at Parkersburg 183 miles downstream continued to rise until the 13th. Between Parkersburg and Cincinnati a large volume of water was discharged into the trunk stream and as a consequence the flood at Cincinnati was in the form of a long drawn out swell without a pronounced crest, although the highest point reached was 62.2 feet at 6 p. m. of the 14th, 0.3 foot higher than at 8 a. m. of the same date. The river at Cincinnati remained above the 60 foot stage for about 5 days. Below Cincinnati the flood wave was of similar form, the river rising by a small amount each day and finally cresting at a stage only a small fraction of a foot above the stage 24 hours preceding. The crest of this flood appears to have passed from Pittsburgh to Cincinnati at the rate of 4.4 miles per hour and from Cincinnati to Cairo at the rate of 1.8 miles per hour. The time required for this flood to pass Cincinnati and the relatively high stages in both the Tennessee and Cumberland foreshadowed a slow crest movement in the lower river.

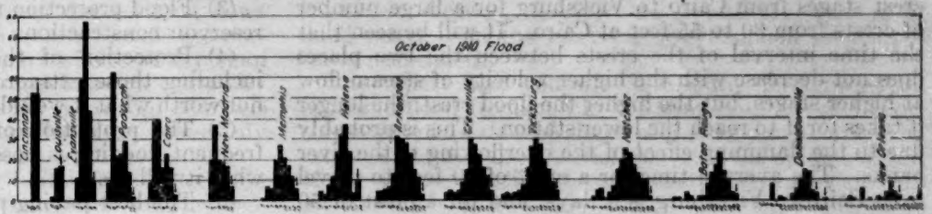


FIG. 3.—Freshet of October, 1910, due to heavy rains in lower Ohio Valley.

The severe flood of March, 1907, in the upper Ohio affords an example of an intense flood in the headwaters of a stream which flattens out as it reaches the lower reaches because of inadequate tributary support.

The flood in question was due to a combination of heavy rain irregularly distributed, moist snow, and high temperature; the latter continued over two days and caused a run-off from melting snow sufficient to cause a break-up of the ice in the main streams and their tributaries. The high temperature on the 14th was effective in producing a crest stage in both the Youghiogheny and Kiskiminetas, two of the main tributaries of the Ohio that converge close to Pittsburgh, and it was mainly to the very heavy flood flow of these two rivers that an unprecedented stage was reached at Pittsburgh on the early morning of the 15th. The Muskingum, which enters the Ohio on the right bank at Marietta, Ohio, contributed a large flow on the 15th which had the effect of advancing somewhat the time of the crest in the Ohio at Parkersburg. The exact time required by the crest to pass from Pittsburgh, Pa., to Louisville, Ky., was 126 hours, or at the rate of 4.8 miles per hour; from Louisville to Cairo the rate of movement was diminished to 3.6 miles per hour. The Mississippi at Cairo, when the Ohio flood reached it, was at a moderate stage and slowly falling. The crest of the Ohio flood reached Memphis in 6 days, Vicksburg in 16 days, and New Orleans in 20 days. The 24-hour rise during the early part of the flood is graphically shown in figure 4 for the stretch of the river—Pittsburgh, Pa., to New Orleans, La.

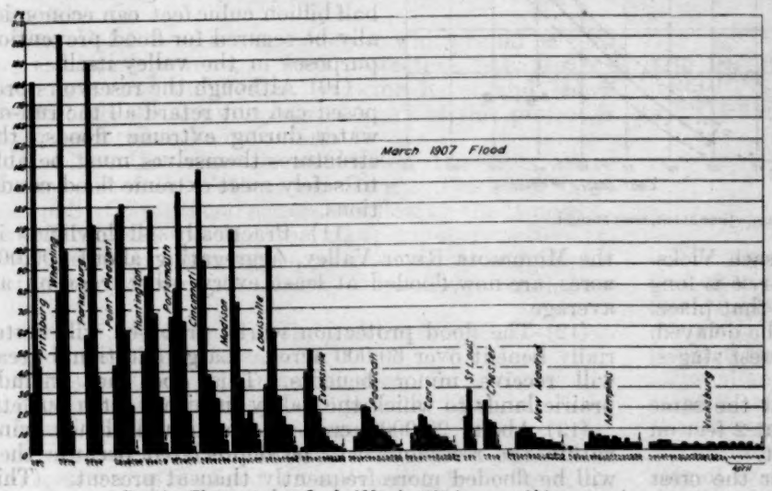


FIG. 4.—The great snow flood of March, 1907, in upper Ohio.

In general, it may be said that the average crest movement Pittsburgh to Cincinnati is 3.4 days, Cincinnati to Cairo 6.6 days, and Pittsburgh to Cairo 10 days, with wide departures due to the tributary effect of the Tennessee and Kentucky Rivers.

For the Mississippi the crest movement Cairo to Memphis for floods of 50 feet on the Cairo gage is very close to 5 days, with a possible variation of a day on either side; for great floods Cairo to Vicksburg the average interval is 16 days, with a possible variation of 4 days on either side due to tributary effects below Memphis. Crest stages of small floods and freshets travel with almost twice the speed of the crests of great floods.

Mr. Herman W. Smith of the river and flood division has also determined the time interval between Cairo, Ill., and Vicksburg, Miss., respectively, and the relation which subsists between crest stages at the two places. His note and the illustrations which accompany it may be used as a basis for forecasting crest stages at Vicksburg as soon as the crest has been reached at Cairo.

RULES FOR FORECASTING THE CREST STAGES AT VICKSBURG, MISS., BASED UPON THE STAGES AT CAIRO, ILL.

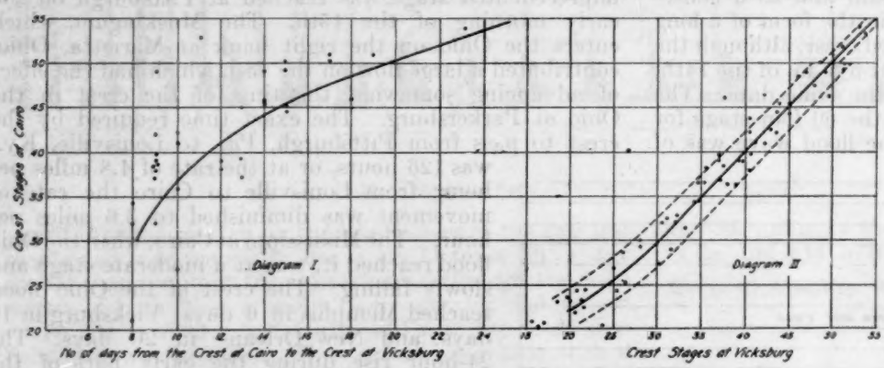
By HERMAN W. SMITH.

[Washington, D. C., October, 1920.]

Vicksburg is 602 miles below Cairo. The velocity of the current at a 25-foot stage is about 3 miles per hour and at a 45-foot stage it is about 4.7 miles per hour. This would give the time for stream flow from Cairo to Vicksburg as 6 days for high stage and about 8 days when the river is at 25 feet.

Figure 1 gives the time intervals for the travel of the crest stages from Cairo to Vicksburg for a large number of crests from 30 to 55 feet at Cairo. It will be seen that the time interval of the crests between the two places does not decrease with the higher velocity of stream flow at higher stages, but the higher the flood crest, the longer it takes for it to reach the lower station. This is probably due to the damming effect of the overflowing of the river banks. The average time for a crest of 30 feet to travel from Cairo to Vicksburg is 8 days, and for a crest of 50 feet, 20 days.

The character of the rise has a marked effect on the time interval for the crest. When the rise is rapid at Cairo and then falls rapidly, the crest will reach Vicksburg from 2 to 8 days sooner than when the rise is long sustained at Cairo after the crest has reached that place. The higher the crest the longer the crest will be delayed.


Crest Stages at Cairo
No of days from the Crest at Cairo to the Crest at Vicksburg
Diagram I
Crest Stages at Vicksburg
Diagram II

FIGS. 1 and 2.—Gage relations, Cairo and Vicksburg—time at left, crest at right.

Figure 2 shows the relative height of the crest stages, Cairo and Vicksburg.

Above 30 feet the average crests are about the same at the two places, but there is a range of about 2 feet on either side of the mean for stages below 50 feet.

When the river falls rapidly at Cairo after the crest reaches that place, the crest stage at Vicksburg will be lower than at Cairo, generally from a few tenths to a foot, but it may be as much as 2 feet when the crest is below 50 feet.

When the streams below Cairo are high and deliver their crests in time to meet the crest from Cairo it will increase the crest stage at Vicksburg, sometimes by as much as a foot or two.

When the rise at Cairo is long sustained and the Mississippi is high above Cairo, the crest stage at Vicksburg will frequently be from a few tenths to as much as a foot higher than at Cairo. With a crest stage below 50 feet the difference may sometimes be as much as 2 feet, if the tributary streams below the Ohio are high.

FLOOD PREVENTION IN THE MINNESOTA VALLEY.

An abstract of the report of Mr. E. V. Willard, Minnesota State Commissioner of Drainage and Waters. (Investigation by Mr. Adolph F. Meyer, consulting engineer; report obtained through courtesy of Mr. H. W. Richardson, meteorologist, Duluth, Minn.)[1]

Some of the conclusions reached by Mr. Meyer are as follows:

(1) Material reduction of devastating floods in the Minnesota River Valley is possible, but some lands must be sacrificed for the benefit of others.

(2) No substantial protection can be accomplished by either levee construction or channel improvement.

(3) Flood protection must and can be accomplished by reservoir construction.

(4) Protection of the valley lands from all floods, including those extraordinary ones of rare occurrence is not worth what it would cost.

(5) The protection of most of the valley lands from frequent flooding is possible and worth more than twice what it will cost.

(6) The best paying project is that which protects the valley lands from all floods except those which may be expected to recur, on an average, once in 10 or 15 years.

(7) Automatic retarding basins are not practicable on the Minnesota River. Manually controlled reservoirs must be used.

(8) No satisfactory reservoir sites are available, on the tributary streams.

(9) Three large reservoirs with a total capacity of eighteen and one-half billion cubic feet can economically be secured for flood prevention purposes in the valley itself.

(10) Although the reservoirs proposed can not retard all the run-off water during extreme floods, the structures themselves must be able to safely meet extreme flood conditions.

(11) Practically all lowlands in the Minnesota River Valley, aggregating about 100,000 acres, are now flooded at least every other year on an average.

(12) The flood protection works proposed will materially benefit over 60,000 acres. Large additional areas will receive minor benefits. This does not include prairie lands to which the valley furnishes ditch outlets.

(13) About 20,000 acres of agricultural lands lying within the reservoirs will be depreciated because they will be flooded more frequently than at present. (This area does not include areas classified as lakes, ponds, sloughs, or marshes on the Government maps based on the surveys of 1909–10.)

(14) On the basis of the available data the cost of the proposed project is estimated at nearly $2,000,000.

(15) Minnesota needs to appropriate funds for topographical surveys and hydrological observations.

(16) All three reservoirs here proposed must be planned and operated as a single system or full benefit will not be derived therefrom.

(17) The reservoirs proposed are for flood prevention purposes and not for power or navigation. They must be operated as intended in order to be effective.

[1] *Bulletin of the Affiliated Engineering Societies of Minnesota*, December, 1920.

An increase in the bankful capacity of the main stream at critical sections is proposed, but channel enlargement to provide for flood-flow capacity is not feasible.

Reservoir sites.—Many of the destructive floods which occur in the Minnesota River Valley are local in character. Flood producing conditions seldom, if ever, occur simultaneously with equal intensity over such large and diverse areas as those included within the Minnesota River drainage basin. Early spring floods caused by the melting of accumulations of snow come nearest to being general throughout the entire valley. The most destructive floods, however, are those which occur during the crop season. Since they are largely due to flood flows from individual tributaries, these summer floods are normally much more severe in one part of the valley than in the remainder. If these floods are to be prevented by retarding the flood waters until the available channels can carry them away, then reservoirs must necessarily be located in various portions of the drainage basin.

Four "reasonably satisfactory" sites for the location of reservoirs were found near Ortonville, Montevideo, Delhi, and New Ulm. Big Stone Lake, near Ortonville, with an area of about 20 square miles, can be used for retarding the flood waters of the Little Minnesota and Whetstone Rivers. These are extremely flashy streams that at times cause much damage in the upper valley.

Lac qui Parle, above Montevideo, area about 4 square miles, constitutes a natural reservoir, which, with Marsh Lake and large adjoining areas of marsh and low-lying agricultural lands, can be utilized for retarding the flood waters of the Lac qui Parle and the Chippewa Rivers.

Near Delhi there is a possible site which could be used for combined power and flood protection, reducing the flood crests of the Yellow Medicine River and Hawk Creek. The flood protection feature of this project is not considered to be important.

The New Ulm reservoir would store the water above the mouth of the Cottonwood River. This river flows so rapidly that its flood waters now flow up the Minnesota and fill the valley before the upper tributary waters arrive, and the two proposed upper reservoirs would provide only incomplete protection to the valley around New Ulm.

The storage capacity of three of the four proposed reservoirs would be as follows:

Big Stone Lake, 4 billion cubic feet.
Lac qui Parle reservoir, 9 billion cubic feet.
New Ulm, 5.5 billion cubic feet.

A reservoir on the Blue Earth River is thought to be unnecessary, as its flood waters coming from the south usually pass Mankato before the arrival of the Cottonwood water, and retardation of the Blue Earth would only aggravate conditions at Mankato.

Automatically controlled retarding basins, such as those used on the Miami River, are inapplicable to the Minnesota basin, mainly on account of the long duration of the floods and the irregularity of the flood-producing combinations.

On account of the rapidly increasing channel capacity from Big Stone Lake to Mankato, the size of flood protection reservoirs provided per square mile of tributary drainage area should increase *upstream*. The channel below Big Stone Lake, for example, has a capacity only about one-tenth as large as that of the channel below Montevideo, even though the drainage area tributary to Big Stone Lake is one-fifth as great as that tributary to the Minnesota at Montevideo. Such reservoirs should also be relatively larger for small basins than for large ones, because the smaller the area the larger the rainfall and run-off in inches depth over that area, which will occur with given frequency.

In the operation of the proposed reservoirs within the limits of their capacity no water should be discharged from any one of them until it is full, or the stage in the reservoir next below it is falling, indicating that the inflow is less than the outflow. In general, this means that the upper reservoirs should be filled first and emptied last; or, in other words, the storing of water should continue in the upper reservoirs until wasting has begun in the reservoir next below. During sudden freshets on the tributaries between any two reservoirs the wasting of flood water from the reservoir above should be temporarily suspended.

The report also contains interesting paragraphs on probable flood frequency in the Minnesota River Valley, the economic value of flood protection, meteorological tables, and other flood statistics. It is the opinion of Mr. Meyer that floods like those in the upper valley in 1919 are not likely to be approached oftener than once in 40 years, and that bankful stages are probable every year in the lower valley and every two years above. Tables and curves were used to form an estimate of the depreciation of cultivated lands by flooding during the crop season, and they indicate that land on which a grain crop is lost once in every three years has no capital value for cultivation purposes. As flood losses become less frequent, land values increase rapidly until only one crop is lost every 10 or 15 years; beyond this point the increase in capital value is very slow.—*H. C. F.*

THE INFLUENCE OF FOREST AREAS IN NONFORESTED REGIONS UPON EVAPORATION, SOIL MOISTURE, AND MOVEMENT OF GROUND WATER.[1]

By Prof. IRWIN T. BODE.

[Dept. of Forestry, Iowa State College, Ames, Iowa.]

[Author's Abstract.]

[Read before Iowa Academy of Sciences, Annual meeting, 1920.]

The paper includes the results of a series of studies carried on in the northeastern part of Iowa during the summer of 1919. The work covers the comparison of the evaporation and soil moisture conditions obtaining on forested and nonforested sites, and the influence that the forested areas have as to the checking of run-off, the absorption of moisture into the soil, and the response of the various soils at various depths to precipitation.

The direct influence of forest cover in checking the rate of evaporation is emphasized, there being a distinct decrease in evaporation with the succession from open to brushy and in turn to timbered sites. There is also evident a rather direct relation between the rate of evaporation and the aspect of slopes, and between the evaporation and the wind velocity.

The studies of soil moisture show the tendency of the timbered soils to a higher moisture content and the greater absorbtive qualities. There is apparent a direct relation of the forest cover to the checking of the run-off and to the rate of permeability of soil moisture to the lower soil layers. The movement of ground water appears to be distinctly retarded in the case of the timber soils. The results all indicate the importance of forest cover on the slopes of watersheds, even where the forest areas are comparatively limited in extent.

[1] To be published at Des Moines, Iowa, in the *Proceedings of the Iowa Acad. of Sci.*, for 1920.

DISCUSSION.

With reference to evaporation, the thing which Prof. Bode measured was essentially the evaporative capacity with reference to the porous cup atmometer and its environment. This is the same thing which has been described by Livingston and others as "the evaporative power of the air."

Evaporative capacity, and the evaporative loss from the soil, may be, and usually are, quite different, the former being the larger, since the latter is the product of the evaporative capacity and a factor termed by the writer "Evaporative Opportunity," and which is approximately proportional to the percentage of saturation of the soil surface, and is generally less than unity.

If, therefore, when Prof. Bode speaks of evaporation, it is assumed that he means "Evaporative Capacity," and not actually evaporation loss from the soil, then his conclusions are undoubtedly correct, and are in accordance with numerous other investigations along the same line.

More experimental work is needed to determine the precise relations of the actual evaporation loss from the soil in woods, sodded fields, and cropped fields. Very likely the actual loss in sodded fields is greater than in most crops or forests. In considering the possible effects of forests as conservators of moisture, other and more important factors than evaporation from the soil must be considered. These include rainfall interception and transpiration.

It is also important to bear in mind that a comparison of forests with a sodded field may lead to conclusions which will not hold as regards the relation of a forest to a cropped field (of corn, for example).

In the forest the sum of the water losses is undoubtedly greater than in the ordinary meadow or pasture with short grass, for in the latter case interception and transpiration are relatively slight, even though the evaporation from the soil is materially greater than in the forest.

As to soil moisture, the author's experiments indicate less moisture in the surface layers in the open than in the forest, but more moisture in the open below 20 inches depth. Can it be fairly assumed that the moisture content in the forest is greater than in the open from these measurements, even though their numerical average does so indicate? If measurements at 4, 5, and 6 feet, or other depths down to the water table or rock had been taken, these would undoubtedly have shown results similar to those at 20 to 36 inches depth, and would have thrown the average of moisture content strongly in favor of the open field. Are not these results precisely what would be expected?

After a shower the moisture of the surface layers of the soil is more rapidly removed by evaporation in the open than in the forest, and the surface layers of the soil become dryer in the open. At greater depths, however, the smaller losses through interception and transpiration and other factors combined indicate that there should be, as was here found, a greater soil moisture below the influence of surface evaporation in the open.

Prof. Bode suggests that the soil in the forests was more open-textured than that in the open. Even a slight difference in this regard might vitiate the conclusions from such experiments. Soil moisture values are expressed as percentages of dry weights. The greater the porosity, therefore, the smaller the *actual volume* of water corresponding to a given dry weight moisture percentage. In other words, a slight excess of moisture percentage might be merely the result of an excess in porosity, without an actually greater water content.

It is unfortunate that this point was not determined, especially as observations along this particular line are very meager. Similar results have recently been published by Dr. Arnold Engler.[1]—*Robert E. Horton.*

TYPHOON IN THE PHILIPPINES.

By JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I., November, 1920.]

A destructive typhoon visited the Philippines at the beginning of November, causing much damage to property and to the crops in the Visayan Islands, Mindoro, and southeastern Luzon. Several small boats have been reported as either totally wrecked or badly damaged, with a corresponding considerable loss of life.

As no observations have been received as yet from Yap, Western Carolines, it is impossible to ascertain whether the typhoon was formed near that region of the Pacific Ocean or rather near the Philippines.[2] Clear signs of the existence of the typhoon and of its character as dangerous to the Visayas were noticed at Manila Observatory on November 2, and proper warnings sent out one day before the storm struck the easternmost part of the Visayas. The center of the typhoon must have been situated at 2 p. m. of the 2d near 130° longitude E. and 11° latitude N., moving almost due west. Shortly after noon of the 3d the typhoon reached the island of Samar, passing over, or very close to the south of, Borongan (125° 25′ longitude E., 11° 35′ latitude N.), where a barometric minimum as low as 729.52 mm. (gravity correction not applied) was observed at 12.30 p. m. The typhoon inclined slightly to the NW. while moving between Samar and Mindoro, so that at 6 a. m. of the 4th the center was situated near 121° longitude E. and in about 12° latitude N. The fury of the storm was particularly felt in Samar, northern part of Cebu and Negros, Masbate, Romblon, northern Panay, and Mindoro.

Once in the China Sea the typhoon moved again almost due west, and it reached Indochina in the morning of the 6th, the center being situated at 10 a. m. of that day in about 109° longitude E. and 13° latitude N.

The rate of progress of this typhoon while crossing the Philippines was of about 14 or 14.5 per hour.

[1] Influences of Forests on Water Supply, Swiss Central Institute for Forest Investigations, vol. 12. Zurich, 1919.

[2] See reference to report of Dutch S. S. *Bali*, in review of the weather of the North Pacific Ocean for November, p. 667.

NOTES, ABSTRACTS, REVIEWS.

Sir Joseph Norman Lockyer, Astronomer and Meteorologist.[1]

[1836-1920.]

[Excerpts from *The Meteorological Magazine*, September, 1920, 55:181-182.]

The death of Sir Norman Lockyer, on August 16, marks the end of the career, not only of a famous astronomer and investigator of the physics of the sun, but also of a keen meteorologist whose claim to fame in that department of natural knowledge will increase as time goes on and "the thoughts of men are widened with the process of the suns."

In science he began as an amateur, for he was educated at various private schools which had no laboratories in those days, and at the age of 21 received an appointment in the War Office. * * * He left the War Office [in 1870] to become secretary of the Duke of Devonshire's Royal Commission on Scientific Instruction and the Advancement of Science. * * *

It was the study of solar physics that brought him into relation with meteorology. Certain indications of relationship between the frequency of sunspots and the phenomena of the earth's atmosphere had been brought forward by Charles Chambers as regards Indian rainfall, and by Charles Meldrum as regards the frequency of tropical revolving storms in the region of Mauritius. * * * To develop the relationship into practical utility required on the one hand the study of the sun, and on the other hand the study of the meteorology of the earth as a whole. The case for this cooperative study was set out by Sir Norman Lockyer at a meeting of the International Meteorological Committee at Southport in 1903, when that committee met simultaneously with the British Association, of which Lockyer was then president. * * *

The meteorological side involved the study of the meteorology of the globe as a whole, and the prosecution of that study required the cooperation of meteorologists all over the world. The work of compilation was intrusted mainly to Dr. W. J. S. Lockyer, Sir Norman's youngest son, and to their activity we owe a number of volumes on the distribution of pressure and rainfall over the globe, the barometric seesaw, the meteorology of Australia, and the circulation of air in the Southern Hemisphere. * * *—*Napier Shaw.*

DR. GEORGE C. SIMPSON SUCCEEDS SIR NAPIER SHAW AS HEAD OF THE METEOROLOGICAL OFFICE.[2]

The retirement of Sir Napier Shaw, Sc. D., LL.D., F. R. S., from the directorship of the Meteorological Office took place on September 6. The Air Council have appointed Dr. George C. Simpson, F. R. S., to succeed him. Dr. Simpson is best known to meteorologists by his theory of thunderstorms and by his work as meteorologist and physicist to the Scott South Polar Expedition, which was discussed by Dr. H. R. Mill in our July number. He has held an appointment on the staff of the Indian Meteorological Department since 1906.

[1] For a much more detailed biographical sketch, see *Nature*, London, Aug. 19, 1920, pp. 781-784.

[2] Reprinted from *The Meteorological Magazine*, September, 1920, 55:164.

THE UNIFICATION OF THE METEOROLOGICAL SERVICES OF BRITAIN.[1]

The unification of the national meteorological services was completed on August 12, 1920, on which date the special meteorological service established during the war at the Admiralty was incorporated with the Meteorological Office. The Air Ministry has thus become responsible for all branches of official meteorological work.

METEOROLOGY AT THE BRITISH ASSOCIATION MEETING AT CARDIFF, AUGUST 24-27, 1920.

[Excerpts from *The Meteorological Magazine*, September, 1920, 55: 169-172.]

There was very little sign of activity in meteorology in the program of papers prepared for the meeting of the British Association at Cardiff this year. * * *

A paper was presented by Prof. S. Chapman[1] on "Terrestrial Magnetism, Aurorae, Solar Disturbance and the Upper Atmosphere," a further development of the subject so well set out in a recent paper before the Royal Meteorological Society. In Section B (Chemistry) Dr. J. S. Owens gave an account of the recent work of the Committee on Atmospheric Pollution in the investigation of the acid impurities of the atmosphere. * * *

THE SPECTRUM AND THE THEORY OF THE GREEN FLASH.

By A. DANJON AND G. ROUGIER.

[Abstracted from *Comptes Rendus*, Paris Academy, Oct. 26, 1920, 171: 814-817.]

In favorable cases, it is possible to see the disk of the setting sun bordered by a red and a green fringe during 10 minutes preceding disappearance; special spectrophotographic arrangements show that the spectra of the setting sun and the green fringe differ only in the suppression of the red, and conversely the spectrum of the lower edge shows only the extreme red. These observations decide definitely in favor of the atmospheric dispersion theory of the green flash, and against the anomalous dispersion theory of Julius, for the numerous sharp telluric lines have the same aspect in the spectrum of the green flash as in that of the solar disk. Certain peculiar conditions, whose existence is made manifest in the appearance of the green flash, cause a momentary enlargement and brightening of the flash, giving it a duration of a few seconds, instead of only a few tenths of a second as Julius holds would result.

Brewster's bands reduce the spectrum to practically green and red, separated by atmospheric dispersion, thus causing the sharp limits to the fringes about the sun; the green flash is much easier to see when Brewster's bands are intense. The phenomenon is greatly modified by the condition of the atmosphere, etc.; all the most favorable conditions for being able to observe it are united over a sea horizon, but also frequently occur in other localities.—*E. W. W.*

[1] *See* MO. WEA. REVIEW, December, 1919, 47: 879, "Electrical phenomena in the upper atmosphere," by S. Chapman.

A STUDY OF THE RESIDUAL IONIZATION IN A GAS WITH REFERENCE TO TEMPERATURE EFFECTS.

By C. H. KUNSMAN.

[Abstracted from *Physical Review*, October, 1920 (2), 16: 349-361.]

Special apparatus permitted a quick and accurate test of the insulation properties under the same conditions as those under which the ionization tests were made; and a subjection of the instrument to a wide range of temperature. Results show that the number of ions generated per cubic centimeter within an airtight chamber is 8.22 per second in the basement of the physical laboratory, University of California, and 4.15 over the Pacific Ocean.

This electrical conductivity, or residual ionization, is not due to molecular impact of thermal agitation; the apparent increase in ionization as observed at high altitudes is solely a temperature effect, and is due to an increase in conduction over the insulation; the effect of changes in temperature on the insulation system of an apparatus of this kind is sufficient to account for the daily and seasonal apparent variations of the residual ionization as reported by some observers, and is not due to a variation of the ionization of the gas within the chamber.

It would seem that it is not necessary to assume, as has been done by previous investigators, that there is a highly radioactive cosmic layer in the upper atmosphere; or that the sun is a source of penetrating radiation sufficient to generate 90 ions per cubic centimeter per second.—*E. W. W.*

ON THE VARIATIONS OF THE RADIOACTIVITY OF THE SPRINGS OF BAGNOLES-DE-L'ORNE AND THEIR RELATION TO RAINFALL.

By P. LOISEL.

[Abstracted from *Comptes Rendus, Paris Academy of Sciences*, Nov. 2, 1920, 171: 858.]

The principal portion of the variations in the intensity of the radioactivity of the springs of Bagnoles-de-l'Orne is found to depend upon the time and amount of rainfall. Apparently the waters percolate through the earth, become charged with the radioactive material, and then reappear at the springs; a maximum of intensity occurs several days after the rain. This would appear to be a universal phenomenon, and one worthy of extended study from geologic, mineralogic, and therapeutic standpoints.—*E. W. W.*

CAN WE EXTEND OUR ANNUAL TEMPERATURE RECORD BACK FOR 30,000 YEARS?[1]

Baron Gerard De Geer, of Stockholm, Sweden, has come to the United States with several assistants in order to connect the glacial chronology of Scandinavia with that of America and to count the annual layers of glacial clays back, perhaps 10,000 years farther into the past. Summer after summer the receding continental glaciers left distinct layers of clay on the bottoms of fresh-water lakes. Summers warmer than usual seem to have been responsible for the thicker layers, and summers cooler than the average, for the thinner layers. The zigzag plots of the thicknesses of successive layers of clay remind one strongly of the form of the "curve" of temperatures of successive summers at present—except that the clay "curves" show some great changes due undoubtedly to important changes in glacial drainage.

But perhaps we are jumping at conclusions when we ascribe to temperature departures the thickness of sediment deposited from glacial waters. Perhaps there was a winter of excessive snowfall which, in even a normal summer, would have melted sufficiently to supply an abnormally great volume of water. Before we can convert glacial clay laminæ into records of temperature and precipitation, a study of deposition from existing glaciers under different departures of summer temperature and winter snowfall and rainfall appears to be necessary.

Nevertheless, the situation looks hopeful. We have before us: Accurate instrumental observations for somewhat more than a century, historical records of ice in rivers and of unusual seasons for a dozen or more centuries farther back; tree rings giving approximate annual conditions back a score of centuries farther; then glacial clay laminæ back 100 to 250 centuries more. Beyond this our annual record fails and we measure climatic epochs by units tens of thousands to millions of years in length.

Our passing years sink into insignificance before this array of thousands and thousands of years, and our "stationary" climate becomes but a transitory state when judged by the units of time given by the earth's record of weather.—*Charles F. Brooks.*

[1] Discussion suggested by two notes in *Science*, Sept. 24, and Nov. 26, 1920, N. S. vol. 52: 284; 502-503, and by Baron De Geer's address before the Geological Society of Washington, Dec. 7, 1920.

SEASONAL DEPOSITION IN AQUEO-GLACIAL SEDIMENTS.

By ROBERT W. SAYLES.

[Abstract from *Mem. of the Mus. of Comp. Zool. of Harvard Coll.*, Vol. XLVII, No. 1, 1919, 4to, 67 pp., 16 pl.]

The main factors which can produce differential aqueo-glacial sedimentation are the swinging of a stream across a delta; the difference of day and night melting of glaciers; more or less regular cyclonic and anticyclonic conditions during part of the year, with or without rain or high winds; periodic or seasonal winds capable of transporting sediment; tides; and the alternating conditions of summer and winter.

Evidence of seasons (other than the apparent seasonal banding in glacial deposits) in the Permo-Carboniferous have come from New South Wales, Australia, in the discovery of annual rings of growth in trees of Permian age. From Brazil similar evidence of seasons was obtained in fossil trees of the same age.—*C. F. B.*

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C. F. TALMAN, Professor in Charge of Library.

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SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING NOVEMBER, 1920.

By HERBERT H. KIMBALL, Meteorologist.

[Solar Radiation Investigations Section, Washington, Jan. 3, 1921.]

For a description of instruments and exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, 48:225.

On account of unusually cloudy conditions but few solar radiation intensity measurements were obtained at any of the stations during November. Lincoln, Nebr., reports only 4 days in the month with average cloudiness less than 3.9, and solar radiation intensity measurements were obtained on only 5 days. During the last decade the sky was almost continously overcast at all the stations except Santa Fe. However, the monthly means of such measurements as were obtained, differ but little from normal values for November, as shown by the departures in Table 1.

Table 2 shows a deficiency in the total radiation for the month at all the stations, the departure from normal being especially marked during the latter part of the month.

Skylight polarization measurements made at Madison on two days give a maximum of 79 per cent on the 4th and a mean of 76 per cent. At Washington measurements made on 6 days give a mean of 63 per cent and a maximum of 65 per cent on the 13th. These latter are about normal values for Washington in November, but the maximum obtained at Madison is the highest polarization measurement ever obtained at that station.

TABLE 1.—*Solar radiation intensities during November, 1920.*

[Gram-calories per minute per square centimeter of normal surface.]

WASHINGTON, D. C.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75 th meridian time.	Air mass.									Local mean solar time.
		A. M.				*1.0	P. M.				
	e.	5.0	4.0	3.0	2.0		2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Nov. 3	4.37	.....	0.93	1.09	1.24	.....	.....	1.02	0.84	0.77	5.16
4	5.36	0.68	0.83	0.97	1.15	1.37	1.18	0.97	0.88	0.79	5.36
5	5.79	0.76	0.86	0.98	1.22	.....	1.15	1.01	0.92	0.77	4.95
6	5.36	.....	.....	.....	1.25	.....	.....	.....	.....	.....	3.99
13	1.78	.....	0.91	1.03	1.32	.....	1.28	1.16	0.97	0.81	1.78
18	3.99	0.72	0.87	1.03	1.19	.....	.....	.....	.....	.....	4.37
Means	.....	**0.72**	**0.88**	**1.02**	**1.23**	**(1.37)**	**1.20**	**1.04**	**0.90**	**0.78**	.....
Departures	.....	**−0.04**	**+0.02**	**+0.01**	**+0.05**	.....	**+0.03**	**+0.06**	**+0.08**	**+0.05**	.....

* Extrapolated.

TABLE 1.—*Solar radiation intensities during November, 1920*—Contd.

MADISON, WIS.

Date.	Sun's zenith distance.										
	8 a.m.	78.7	75.7	70.7	60.0	0.0	60.0	70.7	75.7	78.8	Noon.
	75th meridian time.	Air mass.									Local mean solar time.
		A. M.				*1.0	P. M.				
	e.	5.0	4.0	3.0	2.0		2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Nov. 4	4.75	.....	.....	1.20	1.37	1.60	.....	1.20	.....	.....	3.45
10	2.06	.....	.....	.....	1.36	1.60	.....	1.14	.....	.....	1.45
13	1.60	.....	.....	1.45	1.36	1.56	.....	.....	.....	.....	1.96
16	2.36	.....	.....	1.21	1.35	.....	.....	1.17	.....	.....	2.26
17	2.36	.....	0.79	.....	.....	.....	.....	.....	.....	.....	3.00
18	3.81	0.59	0.72	0.89	1.09	1.35	.....	.....	.....	.....	3.99
Means	.....	**(0.59)**	**(0.76)**	**1.11**	**1.31**	**1.53**	.....	**1.17**	.....	.....	.....
Departures	.....	**−0.28**	**−0.25**	**−0.04**	**+0.01**	.....	.....	**±0.00**	.....	.....	.....
LINCOLN, NEBR.											
Nov. 2	1.24	0.96	.....	1.23	1.43	1.64	1.43	1.28	1.15	1.06	3.30
4	4.17	.....	1.14	1.26	1.43	1.60	.....	1.27	1.15	1.03	3.99
11	1.78	.....	1.16	1.27	.....	.....	.....	.....	.....	.....	1.88
16	2.16	.....	.....	.....	.....	.....	1.37	1.21	1.06	0.94	2.62
Means	.....	**(0.96)**	**(1.15)**	**1.25**	**(1.43)**	**(1.62)**	**(1.40)**	**1.25**	**1.12**	**1.01**	.....
Departures	.....	**−0.02**	**+0.05**	**+0.03**	**+0.06**	.....	**+0.01**	**+0.04**	**+0.06**	**+0.07**	.....
SANTA FE, N. MEX.											
Nov. 4	1.96	.....	.....	1.25	.....	.....	1.44	.....	.....	.....	2.87
8	3.63	.....	1.18	1.27	1.47	.....	1.45	1.40	1.27	.....	3.15
12	3.15	.....	.....	.....	.....	.....	1.47	1.32	.....	.....	2.87
17	2.87	1.12	1.22	1.33	1.45	1.58	.....	.....	.....	.....	3.45
18	3.45	.....	.....	.....	.....	1.59	1.49	1.37	1.23	.....	3.81
19	3.30	.....	.....	.....	.....	.....	1.50	1.35	1.22	.....	3.30
20	3.30	.....	.....	.....	.....	.....	1.43	.....	.....	.....	3.63
22	2.87	1.08	.....	.....	.....	.....	.....	1.32	.....	.....	3.00
27	2.74	.....	.....	.....	.....	.....	.....	1.26	1.19	.....	2.06
29	1.78	1.23	1.33	1.43	1.54	1.66	1.52	1.35	1.27	.....	2.06
30	1.96	1.25	1.33	1.44	1.57	.....	.....	.....	.....	.....	1.96
Means	.....	**1.17**	**1.26**	**1.34**	**1.51**	**1.61**	**1.47**	**1.34**	**1.24**	.....	.....
Departures	.....	**+0.01**	**+0.05**	**−0.02**	**+0.04**	.....	**+0.01**	**+0.03**	**+0.05**	.....	.....

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning—	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Oct. 29	278	170	233	+ 27	−19	− 8	+379	+1659	.....
Nov. 5	239	136	133	+ 6	−37	− 94	+424	+1401	.....
12	168	209	231	− 42	+53	+ 22	+127	+1773	.....
19	161	52	107	− 28	−89	− 91	− 72	+1147	.....
26	70	59	76	−101	−72	−109	−781	+ 642	.....

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary, Smithsonian Institution.

[Washington, Dec. 29, 1920.]

In continuation of preceding publications, I give in the following table the results obtained at Calama, Chile, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

The processes used for observing by the "short method" have been completed, and in the table are given the values for the days in August, 1920, when the short method was used, which were omitted from the values for August published in the REVIEW for September, 1920. I give also all of the values obtained for September and October, 1920.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity.			Remarks.
					ρ/ρSC.	V. P.	Relative humidity.	
1920.								
P. M.	*cal.*					*c.m*	*Per ct.*	
Aug. 6	1.962	$M_{1.95}$	S—	0.855	0.747	0.11	4	
A. M.								
8	1.926	$M_{2.5}$	S—	.881	.660	.13	10	
	1.919	M_2						
	1.922	W. M.						
9	1.928	M_3	S	.874	.544	.17	16	Cirri in east near horizon.
	1.939	$M_{2.5}$						
	1.944	M_2						
	1.937	W. M.						
10	1.915	$M_{2.5}$	S—	.879	6.27	.24	20	
	1.933	M_2						
	1.922	W. M.						
11	1.927	M_3	S	.880	.661	.19	18	Cirri in east preventing long method.
	1.924	$M_{2.5}$						
	1.923	M_2						
	1.925	W. M.						
14	1.921	$M_{1.92}$	S—	.883	.792	.05	5	Cirri prevented long method, M_3 and $M_{2.5}$.
15	1.926	M_3	S—	.886	.814	.06	8	
	1.915	$M_{2.5}$						
	1.920	W. M.						
P. M.								
18	1.942	$M_{2.15}$	S—	.878	.495	.24	16	Mottled sky in west.
	1.943	$M_{2.5}$						
	1.943	W. M.						
A. M.								
19	1.946	M_3	S	.879	.543	.25	25	Small patches of cirri around high peaks.
	1.932	$M_{2.5}$						
	1.942	M_2						
	1.940	W. M.						
22	1.951	$M_{2.5}$	S	.885	.751	.08	7	
	1.939	M_2						
	1.945	W. M.						
P. M.								
24	1.905	$M_{2.5}$	S—	.885	.797	.10		
	1.897	$M_{2.25}$						
	1.901	W. M.						
A. M.								
Aug. 26	1.939	$M_{1.75}$	S	.883	.697	.12	7	Cirri in east below sun preventing long method.
	1.949	$M_{1.6}$						
	1.945	W. M.						
Sept. 1	1.939	E_0	E	.874	.672	.12	12	
2	1.956	E_0	VG+	.883	.786	.08	7	
3	1.947	M_3	S	.878	.775	.14	9	Some cirri over high peaks.
	1.957	$M_{1.6}$						
	1.952	W. M.						
P. M.								
5	1.927	$M_{2.5}$	U+	.877	.536	.28	14	Cirri in east and some near sun.
	1.954	$M_{1.50}$						
	1.936	W. M.						
A. M.								
6	1.901	E_0	VG—	.870	.570	.24	21	
	1.897	M_2						
	1.875	$M_{2.5}$						
	1.867	M_2						
	1.870	$M_{1.6}$						
	1.885	W. M.						
7	1.951	E_0	VG+	.881	.701	.16	14	
8	1.964	E_0	VG	.879	.701	.13	13	
9	1.918	E_0	E	.887	.673	.15	13	
	1.950	M_3						
	1.942	$M_{2.5}$						
	1.943	$M_{1.6}$						
	1.945	W. M.						
10	1.953	E_0	VG+	.884	.748	.12	9	
11	1.926	$M_{2.5}$	S	.872	.641	.15	12	Small patches of cirrus in northwest and east.
	1.926	$M_{1.60}$						
	1.926	W. M.						
Oct. 1	1.938	E_0	VG+	.872	.590	.30	29	Small patches of cirri scattered about sky.
2	1.912	E_0	VG+	.873	.628	.23	22	Cirri on eastern and western horizon.
	1.933	M_2						
	1.930	$M_{2.5}$						
	1.928	M_2						
	1.928	W. M.						
4	1.946	E_0	E	.881	.730	.15	17	
5	1.951	E_0	E	.877	.757	.14	16	Few clouds low in east.
6	1.937	E_0	S	.875	.692	.18	17	Cirri in north and east.
	1.918	M_3						
	1.928	$M_{2.5}$						
	1.931	M_2						
	1.929	W. M.						
P. M.								
7	1.925	M_3	S—	.881	.737	.18	10	Cirri scattered over various parts of sky.
	1.908	$M_{2.5}$						
	1.917	W. M.						
8	1.937	$M_{1.13}$	S—	.872	.826	.20	7	Cirri in various parts of sky.
	1.947	$M_{1.10}$						
	1.942	W. M.						
9	1.957	M	S	.870	.682	.23	13	Cirri in many parts of sky.
	1.964	$M_{1.6}$						
	1.959	W. M.						
10	1.941	$M_{1.5}$	S—	.876	.763	.19	8	Cirri in eastern and northern parts of sky.
	1.958	$M_{1.33}$						
	1.947	W. M.						
A. M.								
11	1.948	E_0	E	.872	.651	.13	13	Some cirri in west.
	1.959	M_3						
	1.957	$M_{2.5}$						
	1.956	M_2						
	1.956	W. M.						
12	1.954	M_3	S—	.873	.535	.24	23	Small patches of cirrus in north.
	1.929	$M_{2.5}$						
	1.940	M_2						
	1.943	W. M.						
15	1.969	E_0	VG+	.863	.561	.27	20	Sky mottled in east.
16	1.952	E_0	E	.864	.617	.19	18	
17	1.950	M_3	S—	.880	.761	.11	10	
	1.944	$M_{2.5}$						
	1.933	M_2						
	1.944	W. M.						
18	1.943	M_3	S—	.874	.674	.16	15	
	1.939	$M_{2.5}$						
	1.943	M_2						
	1.942	W. M.						
21	1.954	E_0	E—	.867	.631	.28	27	
	1.955	M_3						
	1.948	$M_{2.5}$						
	1.940	M_2						
	1.951	W. M.						
22	1.946	$M_{1.5}$	S	.868	.705	.32	20	
	1.943	$M_{1.45}$						
	1.945	W. M.						
25	1.954	$M_{1.67}$	U+	.868	.717	.33	18	Cirri in many parts of sky.
28	1.943	M_3	S—	.875	.586	.18	17	Scattered cirri prevented long method.
	1.945	$M_{1.87}$						
	1.937	$M_{1.65}$						
	1.942	W. M.						
29	1.948	E_0	VG	.854	.511	.16	19	Few clouds low in east.
30	1.937	$M_{1.10}$	S—	.870	.706	.29	18	Cirri in various parts of sky.
	1.925	$M_{1.00}$						
	1.931	W. M.						

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was not far from the normal at land stations on the American coast and in the Azores and Bermudas, while it was considerably higher than usual over the northern part of the British Isles.

The number of days with gales was somewhat greater than usual over the steamer lanes, and there were from one to two days when winds of gale force prevailed in the Gulf of Mexico, which is exceptional for that locality.

Very little fog was reported by vessels in the steamer lanes and on the Grand Banks, although it was unusually prevalent off the coasts of England and Scotland.

On the 1st a LOW was central near the English Channel and a number of vessels between the Irish coast and the twentieth meridian reported moderate northerly and northwesterly gales, while southeasterly gales were also encountered off the north coast of Scotland.

From the 2d to the 11th the conditions were nearly normal, although a few reports were received denoting heavy weather over the steamer lanes, and fog prevailed in the vicinity of the British Isles during the entire period. Storm logs are as follows, British S. S. *Venusia:*

Gale began on the 3d. Lowest barometer 29.50 inches on the 4th; position, latitude 52° 46′ N., longitude 39° 00′ W. End of gale on the 4th. Highest force of wind 11; shifts of wind S.–SW.

Belgian S. S. *Tongrier:*

Gale began on the 4th. Lowest barometer 29.55 inches at 11 a. m. on the 4th; position, latitude 43° 40′ N., longitude 14° 44′ W. End of gale on the 5th. Highest force of wind, 10; shifts of wind none.

British S. S. *Rhode Island:*

Gale began on the 10th. Lowest barometer 29.29 inches at midnight on the 11th; position latitude 51° N., longitude 41° W. End of gale on the 13th. Highest force of wind, 11; shifts of wind W. by N.–NW.–W.

On the 12th there was a disturbance over the region between Scotland and Iceland, and winds of gale force were encountered in the southerly quadrants as shown by the storm log from the British S. S. *Galtymore:*

Gale began on the 11th. Lowest barometer 28.55 inches at 10 p. m. on the 14th; position, latitude 55° 13′ N., longitude 14° 12′ W. End of gale on the 19th. Highest force of wind, 12; shifts of wind SW.–S. and back to SW.

On the 12th there was a second LOW central near Swan Island in the West Indies, and while moderate winds were reported near the center, vessels in the vicinity of the Mexican and Texas coasts experienced strong northerly gales, with comparatively high barometric readings. Storm log from the American S. S. *Hadnot:*

Gale began on the 11th. Lowest barometer 30 inches at 11.30 p. m. on the 11th; position, latitude 21° 30′ N., longitude 96° W. End of gale on the 13th. Highest force of wind, 10; shifts of wind not given.

On the 13th, as shown on Chart IX, the position of these two LOWS had changed but little since the previous day, with moderate to strong gales off the coast of northern Europe and in the western part of the Gulf of Mexico, while in the latter region the barometer readings were even higher than on the 12th. On the 13th there was a third disturbance central near St. John's, N. F., and westerly to northerly gales swept the American coast from Nova Scotia to Florida.

On the 14th (see Chart X) moderate weather prevailed along the American coast and Gulf of Mexico, but an unusually severe disturbance covered the steamer lanes east of the 50th meridian. Storm logs are as follows:

British S. S. *Rhode Island:*

Gale began on the 13th. Lowest barometer 28.98 inches at midnight on the 13th; position, latitude 49° 18′ N., longitude, 45° 50′ W. End of gale on the 15th. Highest force of wind 11; shifts SW.–NW.–W. by N.

British S. S. *Caronia:*

Gale began on the 12th. Lowest barometer 29.09 inches at 10 a. m. on the 14th; position, latitude 50° N., longitude 27° 18′ W. End of gale on the 15th. Highest force of wind 10; shifts of wind WSW.–W. by S.–WNW.

By the 15th the storm area had contracted considerably, although strong westerly gales were reported between the west coast of Scotland and the 15th meridian, while the barometer readings were considerably lower than on the previous day as shown by the storm log from the Danish S. S. *L. P. Holmblad:*

Gale began on the 14th. Lowest barometer 27.86 inches at 2 p. m. on the 14th; position, latitude, 58° 30′ N., longitude 15° 10′ W. End of gale on the 15th. Highest force of wind 11; shifts of wind not given.

Too much reliance should not be placed on the reading of 27.86 inches, although at Greenwich mean noon on the 14th and 15th the barometer on board this vessel was recorded as 29.12 inches and 28.46 inches, respectively (all readings corrected), which did not differ greatly from those of a number of other ships in the vicinity.

By the 16th the storm area had contracted in extent, and the barometer was considerably higher than on the previous day, although westerly gales were still encountered between the 20th meridian and the coast of Scotland. On the same day there was a second LOW in the Gulf of Mexico, central near Tampa, Florida. This disturbance was similar to that of the 12th and 13th, with strong northerly gales sweeping over the greater part of the Gulf, the Greenwich mean noon barometer readings ranging from 29.80 inches to 30.09 inches. Storm logs are as follows:

American S. S. *Radiant:*

Gale began on the 15th. Lowest barometer 30.08 inches at 10 a. m. on the 15th; position, latitude 23° 41′ N., longitude 90° 42′ W. End of gale midnight of the 16th. Highest force of wind 10; shifts of wind not given.

American S. S. *El Capitan:*

16th, 6 a. m., position, latitude 25° 17′ N., longitude 84° 55′ W. Overcast and partly cloudy, moderate variable breeze until 2 a. m. then fresh SW. and heavy rain. At 2.45 a. m. fresh northerly gale, frequent rain squalls and rough sea.

16th, 6 p. m., position, latitude 25° 49′ N., longitude 86° 12′ W. Partly cloudy, moderate NW. gale, rough sea.

Charts XI, XII, and XIII show the conditions on the 17th, 18th, and 19th, respectively, when the greater part of the ocean was swept by severe gales. Storm logs are as follows:

Belgian S. S. *Tongrier:*

Gale began on the 17th. Lowest barometer, 29.62 inches at 7:41 a. m. on the 17th; position, latitude 37° N., longitude 64° 46′ W. End of gale on the 18th. Highest force, 11; shifts of wind not given.

American S. S. *Elmsport:*

Gale began 16th. Lowest barometer, 29.07 inches at 7:40 a. m. on the 17th; position, latitude 49° 04′ N., longitude 25° 29′ W. End of gale at 9 a. m. on the 17th. Highest force of wind, 11; shifts of wind SW.-S.-SSE.-NNW.

American S. S. *West Carnifax:*

Gale began on the 17th. Lowest barometer, 29.31 inches on the 19th; position, latitude 43° 30′ N., longitude 39° W. End of gale on the 19th. Highest force of wind, 10; shifts of wind WNW.-NNW.

Danish S. S. *L. P. Holmblad:*

Gale began on the 17th. Lowest barometer, 28.46 inches at 8 a. m. on the 17th; position, latitude 57° 25′ N., longitude 21° 40′ W. End of gale on the 17th. Highest force of wind, 11; shifts of wind not given.

British S. S. *Rhode Island:*

Gale began on the 17th. Lowest barometer, 29.06 inches at 8 a. m. on the 18th; position, latitude 44° 40′ N., longitude 58° 35′ W. End of gale on the 18th. Highest force of wind, 10; shifts of wind SSW.-SW.-WSW.-S. by N.

Danish S. S. *L. P. Holmblad:*

Gale began on the 19th. Lowest barometer, 28.52 inches at 2 p. m. on the 19th. Position, latitude 56° 33′ N., longitude 27° 11′ W. End of gale on the 20th. Highest force of wind, 9; shifts not given.

American S. S. *Limon:*

18th, 7 a. m.; position, latitude 19° 37′ N., longitude 83° 39′ W. Moderate gale, heavy sea, rain squalls.
19th, 7 a. m.; position, latitude 23° 16′ N., latitude 83° 50′ W. Moderate gale, heavy sea, squally.
20th, 7 a. m.; position, latitude 25° 14′ N., longitude 80° W. Moderate gale, heavy sea, heavy rain squalls.

This gale must have been of limited extent, as vessels in the vicinity of the *Limon* reported light to moderate winds.

From the 21st to the 23d there was a moderate disturbance of limited extent in mid-ocean, as shown by the following storm log from the British S. S. *Malvern Range:*

Gale began on the 21st. Lowest barometer, 29.13 inches at 8 a. m. on the 21st; position, latitude 46° 50′ N., longitude 39° W. End of gale on the 23d. Highest force of wind, 9; shifts S. by W.-S.-NW.-N

On the 23d and 24th winds of gale force were reported from the region between the 20th meridian and the Irish coast, as well as on Nantucket shoals and in the vicinity of the Bermudas, while on the latter date vessels a short distance north of the Azores experienced moderate northerly gales.

The storm log from the American S. S. *Coldbrook* follows:

Gale began on the 22d. Lowest barometer, 29.74 inches at noon on the 22d; position, latitude 34° 45′ N., longitude 66° 21′ W. End of gale on the 24th. Highest force of wind, 9; shifts WSW.-SW.

On the 25th and 26th the conditions were comparatively featureless, as only a few reports were received from vessels in the steamer lanes denoting moderate gales.

On the 27th and 28th a severe disturbance of limited area swept the west coast of France, and on the 28th and 29th fresh northerly and northwesterly gales were also encountered in mid-ocean, between the 40th and 50th parallels. On the 28th there was a LOW central near Hatteras, and gales from the northeast prevailed i the northern quadrants and from the southwest in the southern.

On the 29th the center of this LOW was near latitude 36° N., longitude 58° W., and northeasterly gales were encountered by vessels between the 55th meridian and the American coast. The conditions in mid-ocean had changed but little since the previous day, as heavy weather still prevailed over the greater part of the steamer lanes on the 29th and 30th.

On the 30th, as shown on Chart XIV, unusually stormy weather for the latitude was experienced in the region between the Bermudas and the 45th meridian.

Storm logs covering the period from the 27th to the 30th are as follows:

British S. S. *Nitonian:*

Gale began on the 27th. Lowest barometer 29.16 inches at noon on the 29th; position, latitude 50° 26′ N., longitude 19° 06′ W. End of gale on the 30th. Highest force of wind 9; shifts of wind SE.-E.-N.-NW.

American S. S. *Carolinian:*

Gale began on the 28th. Lowest barometer 29.77 inches at 4 p. m. on the 28th; position, latitude 35° 52′ N., longitude 74° 28′ W. End of gale on the 29th. Highest force of wind 10; shifts 1 point to NE.

American S. S. *Collingsworth:*

Gale began on the 27th. Lowest barometer 29.38 inches at 4 a. m. on the 28; position, latitude 46° 20′ N., longitude 29° 40′ W. End of gale on the 29th. Highest force of wind 10; shifts W.-NW.

Italian S. S. *Duca degli Abruzzi:*

Gale began on the 29th. Lowest barometer 29.44 inches at 3.20 p. m. on the 29th; position, latitude 36° 30′ N., longitude 59° 30′ W. End of gale on the 29th. Highest force of wind 10; shifts not given.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

The month of November opened with a typhoon approaching the Philippines from the direction of the Caroline Islands. During the period from the 1st to the 5th this storm moved in a WNW. direction across the Philippine Islands and the China Sea, reaching the Indo-China coast in the morning of the 6th. Particulars regarding this typhoon will be found in an article by Rev. José Coronas, S. J., Chief of the Meteorological Division of the Philippine Weather Bureau, on page 658.

The first information of this typhoon is contained in a report from the Dutch S. S. *Bali*, Capt. R. H. Brouwer, Balik Papan (east coast of Borneo), October 26, for San Francisco. On October 29, according to third officer and observer A. L. J. van der Moer, the weather became dull and bad, sky overcast with Ci. St. and Cu. from the south and passing showers. There was a long, moderate N. swell. The *Bali* at Greenwich mean noon of the 29th was in latitude 2° 53′ N., longitude 126° 10′ E., barometer 29.84 inches, wind SSE., 3. Changeable weather was experienced on the 30th, heavy showers alternating with periods of clear sky. The northerly swell continued, the barometer fell slightly and the wind veered to NW.

On the 31st the center of the typhoon passed to the northward of the *Bali*, the course of the ship having previously been changed to SSE. to avoid the center. The lowest barometer recorded was 29.49 inches (reduced and corrected), which occurred at 2 p. m. (l. m. t.) of November 1, the *Bali* being at that time in latitude 7° 28′ N., longitude 138° E. The highest force of the wind was 8–9, WNW. to WSW. The passing of the typhoon was accompanied by a high, wild sea and swell.

On the 3d, according to press reports, this storm caused the wreck of the Philippine coastwise steamer *San Basilic*, en route to Puerto Bello, Leyte Island, with the loss of 48 lives.

So far as known no vessels other than the ill-fated *San Basilic* were greatly involved in this typhoon. Several, however, were slightly under its influence at different times. The American S. S. *West Cadron*, Capt. F. E. Anderson, Honolulu for Manila (Nov. 5), was just coming under its influence on the 2d, having at 8 p. m. (l. m. t.) of that day a barometer of 29.52 inches, with a moderate NNW. gale and rough sea. The *West Cadron's* report ends here and it is not known how deeply involved in the approaching typhoon the vessel became.

On the 5th and 6th the British S. S. *Ixion*, Capt. R. N. Hodgson, Hong Kong for Manila, had a very high sea and heavy NE. swell. The *Ixion* was on the 5th upwards of 400 miles from the estimated position of the center of the typhoon.

This typhoon was closely followed by another, the track of which during the earlier part of its history can, however, only be conjectured. The first report of this second typhoon appears in a warning issued by the Japanese meteorological service on the 11th, in which the center was placed in latitude 21° N., longitude 126° E., depth 29.45 inches, direction N. During the 12th and 13th it moved in a northeasterly direction, the last warning issued placing the center at 6 a. m. of the 13th in latitude 34° N., longitude 146° E., depth 29.61 inches, direction ENE.

It is not improbable that this second typhoon had its origin in the same region as the first one mentioned, that is, near the Caroline Islands. On November 2 the S. S. *Bali*, which two days before had passed not far from the center of the first typhoon, experienced a high ENE. swell, the wind going to NE. and becoming strong. Heavy rain occurred between moments of absolutely clear sky, conditions identical with those as observed on October 30. In the *Bali's* report it is stated that the inference was that another typhoon was passing, this time to the southward. It would have been possible for a typhoon so located to travel in a northwesterly direction and appear to the east of Formosa on the 11th, where the second typhoon was discovered on that date.

While these typhoons prevailed in Asiatic waters conditions were very active in the higher latitudes of the North Pacific, although the reports at hand are not sufficiently numerous to permit of describing the situation over the entire ocean in detail. This activity continued throughout the remainder of the month and into December.

The outstanding features of these extratropical storms were the extraordinarily low pressures recorded in midocean on the 13th and 14th and the intensity of the southwest gale which swept the American coast near the end of the month. This gale caused the wreck on the 26th of the Peruvian barge *W. J. Pirrie*, which went ashore near the mouth of the Quillayute River, and is generally considered to have been one of the worst in the history of the coast.

The British S. S. *Monteagle*, Capt. A. J. Hosken, Yokohama for Victoria, experienced heavy weather during much of the voyage, lasting from the 5th to the 21st. From the 13th to the 15th, during a strong gale, the ship's barometer showed abnormally low readings, 28.30 inches at 8 a. m. of the 14th, 28.12 inches at noon, 28.04 inches at 8 p. m., and 28.06 inches on the morning of the 15th. The *Monteagle*, during the time, was in latitude 50°–51° N., longitude, 170°–161° W. The lowest barometer observed was 27.98 inches. The correction for instrumental error of the barometer, an aneroid, is −0.13 inch, which would make the lowest pressure 27.85 inches. Press reports of the *Monteagle's* voyage state that this was the lowest barometer within the memory of the oldest officer aboard.

On the 14th the Japanese S. S. *Manila Maru*, Capt. T. Somekawa, also from Yokohama for Victoria, when in latitude 50° 19′ N., longitude 162° 6′ W., recorded a barometer reading of 27.70 inches. The correction for the barometer used, an aneroid, is +0.11 inch, which makes the actual pressure 27.81 inches.

At Dutch Harbor (latitude 53° 30′ N., 166° 55′ W.), the pressure at the morning observation on the 15th was 28.46 inches. Lower readings have been recorded at that station on several occasions since its establishment in 1911. The lowest reading of record is 27.68 inches, reported as occurring in the afternoon of November 16, 1912.

While these abnormally low pressures were being recorded on the North Pacific, correspondingly low readings were being made in the North Atlantic, the Danish S. S. *H. P. Holmblad*, reporting a barometer of 27.86 inches on the 14th, when in latitude 58° 30′ N., longitude 15° 10′ W. Reference thereto will be found in the report of weather of the North Atlantic Ocean.

There had been some recovery in pressure in the Aleutian area following the great depression of the 14th and the 15th and at Dutch Harbor readings were slightly above normal from the 17th to 19th. By the 21st, however, the barometer had fallen to 29.04 inches and at the evening observation of the 23d to 28.94 inches. At this time there was a single depression overlying the Aleutian Islands. On the morning of the 24th two centers appeared, one over the Gulf of Alaska, another centered near Dutch Harbor. This condition held throughout the 24th, but had disappeared by the morning of the 25th, when the weather map showed a single center over the eastern part of the Gulf of Alaska, the point of lowest pressure being Sitka with a barometer of 28.82 inches. During the 25th, 26th, and 27th this depression developed to the southeastward causing dangerous southeast to southwest gales on the American coast during the 26th and 27th, reaching a velocity of 93 miles an hour from the south at Tatoosh Island at 3.25 p. m. of the 26th, exceeding all previous records at that station. A velocity of 68 miles from the south was recorded at North Head on the same date.

CHARTS OF TYPHOON TRACKS.

In the section devoted to charts in this issue of the REVIEW will be found charts of typhoon tracks in the Far East for the months of May and June, reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director Zi-ka-wei Observatory, Shanghai, China.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

North Atlantic Ocean.—Boston, November 22.—An iceberg in the steamship track east of Newfoundland was reported in a wireless dispatch to-day. The appearance of ice in mid-Atlantic at this season is unusual * * *.—*New York Evening Post, November 22, 1920.*

British Isles.—During the greater part of November the British Isles lay on the western edge of a continental anticyclone, and under these conditions the month for the most part was a fine one. During the first week, however, and from the 20th to the 24th, sharp frosts occurred at many of the inland stations. The minimum temperatures recorded during the second of these cold spells were lower than any recorded this season. * * * The general values [of the rainfall expressed as a percentage of the normal] * * * were England and Wales, 49; Scotland, 106; Ireland, 110 * * *.—*Meteorological Magazine, November, 1920, pages 258–259.*

France.—Paris, November 8, 1920.—There was a "rain of blood" upon Monte Carlo and Mentone on Saturday night. The downpour began about 6 p. m., accompanied by a strong southeast wind, and when it ended an hour and a half later the roofs, roads, gardens, and luxuriant shrubs of the Riviera were covered with sticky crimson.

The scientific explanation is that the rain clouds had been saturated with red sand from the Sahara Desert * * *.—*The New York Times, November 9, 1920.*

Morocco.—Tangier, November 29.—Many persons lost their lives in a waterspout which yesterday laid waste some sections of this city. A number of houses collapsed during the storm which raged with unprecedented violence.—*Washington Star, November 30, 1920.*

Argentina.—Buenos Aires, November 13.—Four persons lost their lives and severe property damage, including shipping losses, was suffered in this city as a result of a cloudburst, accompanied by a high wind this morning. Many streets and buildings were temporarily flooded.—*Washington Post, November 15, 1920.*

New Zealand.—Wellington, November 1.—There have been heavy floods in the Manawatu district and miles of country are under water.—*Samoa Times, November 6, 1920.*

DETAILS OF THE WEATHER OF THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By W. P. DAY, Observer.

Cyclones.—The number of low pressure areas was below the normal, due to the failure of the southward extension of the Aleutian LOW to deeply infect the continent.

Anticyclones.—The number of HIGHS was much above the normal, the excess being accumulated by frequent invasions from the Pacific and the region of Hudson Bay.

Tables showing the relative number of HIGHS and LOWS by types follow:

November, 1920.

Lows.	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
November, 1920....	4.0	0.0	1.0	0.0	2.0	1.0	0.0	2.0	0.0	10.0
Average number, 1892-1912.....	4.0	2.3	0.6	0.4	1.1	1.0	0.4	0.8	1.0	11.6

Highs.	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
November, 1920.....	2.0	4.0	3.0	1.0	3.0	13.0
Average number, 1892-1912....	2.0	0.9	1.0	1.1	0.2	8.2

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Weather Bureau, Washington, Jan. 3, 1921.]

PRESSURE AND WINDS.

For the month as a whole, pressure was above normal in all parts of the United States and Canada, save over a small area along the Pacific coast from northern California to southern Washington. The pressure was particularly high over the Great Plains region on the 11th and 12th, and in southern and eastern districts on the following few days.

The important storms of the month were confined to the districts east of the Mississippi during the first half, but during the latter half important storms were reported from both the Atlantic and Pacific coasts.

An extensive storm area that covered the Middle West at the beginning of the month and moved to the lower St. Lawrence Valley by the 3d, was attended by general, and frequently heavy, rains over all districts from the Great Plains eastward.

On the 9th and 10th a severe storm moved from the Great Lakes to the New England States attended by high winds and rain or snow over all northern districts from the Rocky Mountains eastward.

A third severe storm developed over the Gulf States about the middle of the month and moved northward along the coast during the 16th and 17th. High winds and heavy rains prevailed over the coast districts, while farther inland, particularly over the southern Appalachian Mountain districts, rain changed to heavy sleet and farther north, in the upper Ohio and lower Lake regions, high winds and unusually heavy snows greatly delayed traffic.

About this time the first important storm of the month approached the north Pacific coast, and precipitation continued for several days in the far Northwest.

On the morning of the 20th a storm of moderate intensity had developed in the upper Mississippi Valley and during the 22d and 23d moved eastward to the middle Atlantic coast, attended by heavy rains, and local thunderstorms in portions of the Ohio Valley, and by heavy rains along the north Atlantic coast.

On the 25th another severe storm entered the far northwestern States and high winds and general precipitation prevailed for several days along the Pacific coast from northern California to Washington.

On the 27th and 28th a moderately low pressure area moved from the middle Gulf States northeastward to the Atlantic coast, attended by heavy rains, particularly in the Gulf States.

The distribution of atmospheric pressure favored high winds in the Lake region and along the north Atlantic coast on several occasions, and on the north Pacific coast on the 25th and 26th.

The prevailing winds were mainly from westerly quadrants over the districts east of the Rocky Mountains, although they were from southerly points in portions of the middle Plains. West of the Rocky Mountains they were mainly from southerly points.

TEMPERATURE.

The mean temperature for the month was well below normal over nearly all southern districts, and over much of the middle Rocky Mountain and Plateau regions, where locally the monthly averages were nearly 10° below the normal. In the Southern States, the middle decade was unusually cold but otherwise the temperatures were not far from normal.

The principal cold wave of the month set in over the upper Missouri Valley on the 9th and gradually extending eastward and southward gave the lowest temperatures for the month over most districts from the Rocky Mountains eastward. Minimum temperatures below zero were reported as far south as Kansas, and they fell below 20° over much of the Gulf region and to 25° in northern Florida.

The warmest periods of the month were on the 1st and 2d, from the Ohio Valley eastward, and northeastward, from the 6th to 8th over the Gulf States, and mostly about the 20th in the Central Valleys and western Mountain districts.

PRECIPITATION.

The month opened with rain in the great central valleys, the West Gulf States, and in the region of the Great Lakes; rain and snow in the northern portions of Minnesota, Wisconsin, Michigan, and New England, and heavy snow in the middle Rocky Mountain region, and the adjacent portions of South Dakota, Nebraska, and Wyoming. During the next two days, the storm moved to the northeastward and precipitation was received in most sections east of the Mississippi River. Toward the middle of the first decade light local rains occurred in the northern border States from the upper Lake region eastward, and during the latter part of this period precipitation occurred in the central and southern Rocky Mountain regions, and from western Texas northeastward to the upper Mississippi Valley and to the eastward, with heavy falls in parts of the lower Great Plains, and heavy local snows in Wyoming and southern Idaho. The first few days of the second decade were marked by precipitation in many central and eastern localities, which was mostly light, except for some heavy falls in the southeast. Toward the middle of the month rain or snow was quite general west of the Rocky Mountains and cloudy, unsettled weather prevailed over the eastern sections of the country, with showers in the south, and light snow in many northern localities. From the 16th to 18th a storm of considerable energy moved rapidly northeastward over the Atlantic States, and, as stated elsewhere, was attended by general and heavy rains in the coast States and by sleet or snow in the Appalachian Mountain districts, the Ohio Valley, and the lower Lake region. Generally fair weather was the rule during the last few days of the decade in most sections east of the Mississippi River, but low pressure prevailed in the north Pacific coast districts and precipitation was frequent in the central and northern sections west of the Rocky Mountains.

Early in the third decade there was considerable precipitation in the great central valleys and to the northeastward, and shortly after the middle of the period, scattered precipitation occurred in the Mississippi Valley and general precipitation in the eastern States. During the last few days of the month, scattered precipitation again occurred in the central valleys, but to westward of the Rocky Mountains very little precipitation was received during the latter part of the month.

For the month as a whole precipitation was light to moderate in all sections east of the Rocky Mountains, except over the Atlantic Coast States, particularly in Virginia and parts of North Carolina where the amounts averaged from 6 to nearly 8 inches, and individual stations reported in some cases the greatest amounts ever recorded in November. It was light in the lower Ohio and middle and lower Mississippi Valleys, also in the greater part of the Rocky Mountain region, and in the northwestern Great Plains, but in the eastern Great Plains the totals were above the seasonal average. Heavier precipitation than is usual for November was received in northern California, southwestern Oregon, and in portions of Nevada, Utah, and Idaho, but in the far southwest the amounts were deficient.

SNOWFALL.

During the last day of October and the first few days of November snow occurred over most Northern States between the Rocky Mountains and the Great Lakes, the falls being heavy in southeastern Wyoming and the western portions of Nebraska and South Dakota, but it soon disappeared under the influence of the warm weather following. Early during the second decade light snows fell in the region of the upper Lakes and in portions of the western mountains, and a little at points in north-central Texas, an unually early date for that locality. A severe storm moving northward along the Atlantic coast from Florida to New England shortly after the middle of the month, brought a heavy blanket of snow over an extensive area from the Ohio Valley northeastward to New England. At points in western New York and Pennsylvania and over the central and western portions of Indiana and Ohio, the falls were unusually heavy for the period of the year, hindering railroad traffic and damaging transmission wires. The greater part of the snowfall for November occurred during this storm, and but little fell thereafter during the month in any portion of the country.

RELATIVE HUMIDITY.

Despite the absence of the usual amounts of precipitation over large portions of the country, there was a marked excess of cloudy weather, particularly in the middle and northern districts to eastward of the Rocky Mountains, and the relative humidity was generally above the average over these districts. In the middle Gulf States there was a slight average deficiency, and similar conditions prevailed from western North Dakota to the Pacific coast, except that the deficiencies were quite large in portions of Oregon and Washington.

SEVERE STORMS.

Aside from the high winds accompanying the low pressure areas over the Great Lakes and along the north Atlantic and north Pacific coasts there were few damaging high winds.

Near Port Arthur, Tex., a severe wind storm on the 26th caused the death of one person and damaged property to the extent of about $100,000; and on the same date high winds at Seattle and Tacoma caused local damage to shipping, electric wires, and plate-glass windows, and high winds on the same date along the Washington coast caused the loss of two vessels and most of their crews.

STORMS AND WARNINGS—WEATHER AND CROPS.

STORMS AND WEATHER WARNINGS.

EDWARD H. BOWIE, Supervising Forecaster.

[Washington, Dec. 30, 1920.]

WASHINGTON FORECAST DISTRICT.

The month from a meteorological standpoint was one of great activity, and more than the usual number of warnings of destructive winds on the Great Lakes and the seacoasts and of cold-wave and special warnings were required and issued. Moreover, the usual forecasts of the general weather and temperature conditions for a week in advance were issued each Saturday morning and distributed through the press associations and from weather bureau stations.

As has been the usual practice, heretofore, a special forecast for election day, the first Tuesday in November, was issued. This forecast was made on Monday, the 1st, and given distribution through the press associations and also telegraphed to the chairmen of the national compaign committees and to the presidential candidates. The forecasts in this particular case were accurate in practically every detail and read as follows:

A disturbance of widespread influence is central this morning over Iowa and moving east-northeastward. It has been attended during the last 24 hours by general cloudiness and rains in the Gulf States, the Great Central Valleys, the region of the Great Lakes, New England, and New York; by rains and snows in the Plains States, Minnesota, northern Wisconsin, northern Michigan, extreme northeastern New York and Maine, and snows in the Rocky Mountain region. The snowfall was heavy in parts of South Dakota, Nebraska, and Wyoming. The western disturbance will advance east-northeastward and be attended by unsettled weather and rains Tuesday—election day—in the Atlantic States, the upper Ohio Valley, and the region of the Great Lakes, with some probability of snow in northern Michigan, Wisconsin, and Minnesota. The weather will be clearing and much colder Tuesday in the Gulf States, Tennessee, and the lower Ohio and central Mississippi Valleys. Fair, cool weather will prevail Tuesday over the Plains States, the Rocky Mountain States, and all far Western States.

Special forecasts of wind and weather were prepared and dispatched each day until the 18th for the guidance of the United States naval vessels *Beaver* and *Mallard* engaged on the salvage of the United States submarine *S–5* off Delaware Breakwater. On the 19th the United States *Beaver* radiographed: "Special daily weather reports to *Beaver* and *Mallard* may be discontinued; thanks for it." It was reported that salvage operations were suspended at this time and probably would not be resumed until the coming spring, when the weather conditions would be more quiet.

On November 16 the following telegram was received from the Rayston Water Power Co., Huntingdon, Pa.: "Could you hazard a rough guess as to total precipitation, Bedford County, Pa., Monday, Tuesday, Wednesday, and Thursday this week." It appears that the available water for running this plant was so low that the question presented itself of shutting down the plant or else using coal at a greatly increased cost of operation. At this time a storm was in the Southeastern States, and it was forecast to move northward, so that assurance could be given that general rains were probable in the immediate future. The reply to this inquiry read: "Approximately 1 inch or more precipitation, including both rain and melted snow, in Bedford County Monday to Thursday." It is reported that the actual fall measured during this period was 1.25 inch.

Special flying forecasts were issued for Army and Navy aviators, and the usual daily forecasts of weather, wind at the surface and at flying levels, for the Army, Navy, and the Post Office Aerial Mail Service routes continued throughout the month.

STORM WARNINGS ON THE GREAT LAKES.

Northeast storm warnings were continued on the 1st on Lake Superior, northern Lake Michigan, and northern Lake Huron, in connection with a disturbance that was central at noon of that day over northern Iowa, and the evening of the same day southwest storm warnings were ordered on southern Lake Michigan, southern Lake Huron, and Lake Erie. This disturbance advanced northeastward attended by rain and snow and strong winds and gales on the Great Lakes. The highest velocity reported was 68 miles per hour from the southwest, at Buffalo. At 10 p. m. of the 3d, southwest storm warnings were displayed on Lake Superior and at 10 a. m., on the 4th, the display was extended over Lakes Erie, Ontario, and northern and eastern Huron. The disturbance making necessary this display was central the night of the 3d near Winnipeg, and the night of the 4th, over Ontario, strong westerly winds and gales occurred as forecast.

On the 8th, at 10 p. m., when a storm was central over Minnesota, northwest storm warnings were displayed on the upper Lakes and the morning of the 9th southwest storm warnings were hoisted on the lower Lakes. The storm under consideration moved rapidly eastward across the Great Lakes attended by strong westerly winds and gales during the 9th.

Northwest storm warnings were ordered at 10 a. m. of the 11th on eastern and central Lake Superior and Lakes Michigan and Huron, and at 3 p. m. of the same day the display of northwest storm warnings was extended to Lake Erie. Strong northwest winds attended by snows occurred during the ensuing 24 hours on these Lakes.

A storm of marked intensity was central at noon of the 16th over South Carolina, and increasing in intensity and moving northward. It was expected to gain great intensity during its continued northward movement, and at 2 p. m. northeast storm warnings were ordered for Lakes Erie and Ontario and at 9:30 p. m. the display was extended west to Lake Huron. The storm acted as expected, and during the night of the 16th and during the 17th strong winds and snow occurred on these Lakes.

A disturbance of moderate but increasing intensity was central the morning of the 20th over western Nebraska, and there were indications that it would move eastward and increase in intensity. Accordingly, northeast storm warnings were displayed at 10 a. m. of this date on Lake Superior, northern Lake Michigan, and northern Lake Huron. The storm moved as expected and increased greatly in intensity, and the morning of the 21st northwest storm warnings were displayed on southern Lake Huron and southern Lake Michigan and southwest storm warnings were displayed on the lower Lakes. This storm was particularly severe on extreme northern Lakes Michigan and Huron. At 9 a. m. of the 21st the displayman at Presque Isle Light reported a whole gale from north by east and terrific sea.

A disturbance of considerable intensity was central the morning of the 29th over western Missouri, and it was expected that it would move northeastward and increase greatly in intensity. Northeast storm warnings were then ordered for the upper Lakes. This disturbance did not gain the expected intensity, and at 10 p. m. the storm warnings were ordered lowered.

STORM WARNINGS ON THE EAST GULF COAST.

On the 15th, at 10 a. m., when the barometer was low and falling over the east Gulf and high and rising over the west Gulf States, northwest storm warnings were ordered for the east Gulf coast. The storm over the east Gulf increased greatly in intensity and moved northeastward and northerly gales prevailed over the Gulf during the night of the 15th and during the 16th.

Also on the evening of the 26th northeast storm warnings were displayed on the Mississippi, Alabama, and extreme northwest Florida coast, at which time a cyclone was central off the Texas coast. The winds increased during the night of the 26th and became of gale force along the coast where warnings were displayed.

STORM WARNINGS ON THE ATLANTIC COAST.

On the 2d, at 3 p. m., southwest storm warnings were displayed along the coast at and north of Cape Henry, when a disturbance was over the Great Lakes, increasing in intensity and moving eastward. During the night of the 2d south shifting to west gales occurred along the coast where warnings were displayed. The highest velocity reached was 68 miles per hour from the southwest at Nantucket, Mass.

On the 9th, at 10 p. m., northwest storm warnings were displayed on the coast at and between Delaware Breakwater and Portland, Me. The disturbance at that time being central over the St. Lawrence Valley; this storm passed rapidly eastward and although strong west and northwest winds attended it, no gales occurred on the coast where warnings were displayed.

On the afternoon of the 11th northeast storm warnings were displayed on the Middle Atlantic and New England coast, in anticipation of a northeastward movement and increase in intensity of a storm that was then central over Florida. Strong west and northwest winds and gales prevailed along these coasts on the 12th.

The afternoon of the 15th storm warnings were displayed at all points on the Atlantic coast at and south of Delaware Breakwater, at which time a disturbance was developing over Florida, and the morning of the 16th storm warnings were hoisted on the coast north of Delaware Breakwater, the warning reading as follows:

Hoist northeast storm warning 9:30 a. m. Cape May, N. J., to Eastport, Me. Southern storm increasing rapidly in intensity and moving northward, increasing northeast winds becoming gales with rain and probably snow off New England and Middle Atlantic coasts. Dangerous for all shipping.

This storm was of great severity during the night of the 16th and on the 17th north of Cape Hatteras.

Storm warnings were displayed the morning of the 22d Sandy Hook, N. J., to Eastport, Me., at which time a disturbance of considerable intensity was over Ohio. The warning of easterly gales was particularly applicable to the New England coast, destructive winds prevailing during the night of the 22d and on the 23d.

The last storm of the month for which warnings were required had its center at 8 p. m. of the 27th over southern Alabama and at 9:30 p. m. northeast storm warnings were displayed on the coast between Wilmington, N. C., and Boston, Mass By the morning of the 28th gales had set in on the Middle Atlantic coast and the display of northeast storm warnings was extended north of Boston to Eastport, Me. During the 28th and 29th gales prevailed on the Middle Atlantic and southern New England coasts.

COLD WAVE AND FROST WARNINGS.

Cold wave warnings were issued on the 8th for the upper Lake region, Indiana, Kentucky, Tennessee and western Ohio and on the 9th for northern New England and extreme northern New York. Much colder weather followed over these regions.

Frost warnings were issued on a number of days for the Eastern and Southern States.

WARNINGS FROM OTHER DISTRICTS.

Chicago forecast district.—The month for the most part was rather mild, but a well marked cold spell covered the district for a week or more, beginning near the close of the first decade. This was in fact the only marked cold wave during the entire month and warnings were issued in advance for every station in the district except the northern Rocky Mountain region. The cold wave developed in the British Northwest on the 8th and moved steadily southeastward over the Chicago forecast district, reaching the eastern limits on the 10th. This wave was immediately followed by two others, so that the temperature remained continuously below the seasonal normal at all stations for more than a week.—*H. J. Cox.*

New Orleans forecast district.—Storm warnings were displayed on the Texas coast at Port Arthur and Galveston, including the Galveston section, November 12 and 26. Small-craft warnings were displayed on the Texas coast on the 11th and 15th, and on parts of the Texas, and Louisiana coast on the 26th. All warnings were justified and no general storm occurred without warning.

Cold-wave warnings were issued for the northern portion of the district at 9:30 a. m., November 9, and repeated for Arkansas and northern Louisiana at night. The area of low temperature moved southward so slowly the warnings were only partially verified. Frost and freezing warnings were issued for all injurious conditions. Freezing prevailed in the sugar and trucking region on the 13th and the 16th to 18th, inclusive, for which timely temperature warnings were issued and sugar cane was windrowed and saved from injury.

Fire-weather warnings were issued on the 8th, 9th, and 20th, and conditions occurred as forecast.—*I. M. Cline.*

Denver forecast district.—November was colder than usual. A cold wave warning was issued at 8 p. m. the 27th for eastern Colorado. This was not technically verified but there was a decided fall in temperature. A local cold wave occurred at Pueblo, Colo., on the 24th, the temperature having fallen 24° to 19° at that place in 24 hours, but the fall of temperature at surrounding stations was moderate during that period.—*A. H. Thiessen.*

San Francisco forecast district.—November, 1920, was unusually stormy in this district. Abundant rains fell in northern California, southern Oregon, and northern Nevada. The amount of snowfall in the Sierra Nevada Mountains was much greater than at the same time a year ago. In southern California, southern Nevada, northern Oregon, Washington, and northern Idaho the precipitation was deficient, due in southern California and southern Nevada to the storm tracks not being far enough south to cause the usual amount of rain. The deficiency in the north was due to a preponderance of high-pressure areas over the Canadian Northwest.

Temperatures averaged nearly normal and there were no severe cold spells, though on many mornings frost formed in the Sacramento and San Joaquin Valleys.

Coastwise shipping suffered a few disasters and many delays on account of the number of stormy days along the coast. On November 5 the barkentine *Edward May* from Callao for the Columbia River, reported that she was about 100 miles off San Francisco for 10 days bucking strong northwest gales. She began leaking badly and put into San Francisco for repairs.

Steamer *G. C. Lindauer* was driven ashore during the night of November 16 by a heavy storm at Albion, Calif. This ship was floated on November 24. Part of her keel was lost through the mishap, but otherwise she escaped in good condition.

The steamer *Joan of Arc* went ashore on the beach near Battle Rock, Port Orford, Oreg., during the night of November 15–16. The crew, including two women, were picked up by lifeboats by the *City of Topeka*. This vessel, valued at $250,000, became a total loss.

Schooner *Bangor*, from Sydney for San Francisco, had her headgear carried away in a strong southeast gale on November 16 while in latitude 39° 8′ north and longitude 124° 5′ west.

The steamer *Westport* was seven days off Crescent City, Calif., after the 16th awaiting a chance to get into the harbor, which she was prevented from doing on account of rough weather.

The Chilean steel barge in tow of the steamer *Santa Rita* went ashore November 26, at Cape Johnston, on the Washington coast south of Cape Flattery. This vessel carried a crew of 14 men and the captain's wife and child were aboard of the vessel. The ship was valued at about $200,000. Fourteen lives were lost and only two of the crew were saved. The ship and cargo will be a total loss.

Steamer *Tamalpais* was blown ashore in Grays Harbor on November 26. She became waterlogged, but was afterwards towed to Hoquiam, where her cargo was discharged and repairs were made.

Advisory warnings were sent to shipping interests in this district on the 1st, 14th, and 30th for storms to be encountered on the first or second day after leaving this coast. In addition, storm warnings were displayed at one or more places on 11 days and small craft warnings on four days. These warnings for the most part were timely and undoubtedly of benefit to mariners.

Frost warnings were issued frequently for northern California and twice for southern California. They were generally verified, though of no great benefit, as the frosts were not heavy enough to cause any great amount of damage.—*E. A. Beals.*

RIVERS AND FLOODS.

FLOODS DURING NOVEMBER.

By H. C. FRANKENFIELD, Meteorologist.

[Dated, December 29, 1920.]

There were no serious floods during the month of November, and those that occurred were in the smaller rivers, as will be seen from the following table:

Flood stages during month of November, 1920.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Roanoke:	*Feet.*			*Feet.*	
Weldon, N. C.	30	18	19	34.0	19
		30	(1)	35.1	30
Neuse:					
Neuse, N. C.	14	17	19	16.3	17
Smithfield, N. C.	14	18	21	17.2	19
Santee:					
Rimini, S. C.	12	20	21	12.6	20
Ferguson, S. C.	12	22	22	12 0	22
MISSISSIPPI DRAINAGE.					
Scioto:					
Larue, Ohio.	11	23	24	11.0	23,24
Circleville, Ohio.	10	24	24	10.0	24
WEST GULF DRAINAGE.					
Trinity:					
Trinidad, Tex.	28	2	2	28.0	2
PACIFIC DRAINAGE.					
Sacramento:					
Red Bluff, Calif.	23	19	19	23.2	19
Willamette:					
Eugene, Oreg.	10	27	27	11.5	27

[1] Continued into December.

The lower Roanoke River was in flood on the 18th and 19th. This rise was unusual for the time of the year, and was a rapid one following a 2 to 4 inch rainfall after a dry period, the rainfall having been heaviest over the central portion of the watershed. Warnings were issued on the 17th, and the crest stage at Weldon, N. C., was 34 feet, or 4 feet above the flood stage, on the 19th. Warnings were also issued on the 17th for the Neuse and Cape Fear Rivers. In the Neuse River the crest stages were from 2 to 3 feet above the flood stages, but the warnings for the Cape Fear River failed owing to the closing of the dam at Buckhorn Falls power plant, 7 miles below Moncure, N. C. This cut off 9 feet from the normal rise at Fayetteville, N. C. Advices had been received that the water at the dam had been virtually emptied, but after the warning had been issued the gates were closed and the rise held up. Another and greater rise was in progress in the Roanoke River on the last day of the month and report thereon will be made next month.

Matured crop losses were about $5,000, and about $15,000 worth of property were saved through the warnings.

Warnings of flood stages in the Pedee River at Cheraw, S. C., were issued on the 17th, but failed decidedly. The failure was due to unreported deficiencies of precipitation over a portion of the upper watershed and to the drawing

down of 14 feet of water in one pool of great storage capacity, also unreported. The filling of this pool after the rains materially reduced the sharp rise in the river, and another pool farther down further flattened the flood crest that remained.

Warnings of marked rises were also issued on the 17th for the lower Saluda, lower Broad and Congaree Rivers of South Carolina. These warnings were justified. Copious rains below Camden and Columbia, S. C., also caused moderate flood stages in the Santee River. There was no loss or damage.

Moderate local floods occurred in the Scioto River of Ohio on the 23d and 24th, but apparently no damage was done.

For the first time in the history of the Bismarck, N. Dak., station, warm weather caused the early breaking up of the ice in the Missouri River after it had been frozen to such an extent that teams and automobiles could cross. This occurred on November 15, 23, and 27, at Williston, N. Dak., and at points below on November 29. Warnings of the coming of the ice and rising waters were issued a sufficient time in advance for precautionary measures to be taken. A new highway bridge is in course of construction across the Missouri River at Bismarck, and the timely warnings enabled the workmen to escape with their lives. The only damage was the tearing out of the trestle of the new bridge, and amounted to only a few thousand dollars. After the ice passed out a steamboat was brought up from Deapolis to Bismarck, marking the latest navigation ever known on the Missouri River in North Dakota.

The moderately high stages in the lower Trinity River of Texas during the early days of the month were forecast in the latter part of October. There was no damage of consequence, as live stock had previously been removed to places of safety.

The only other floods occurred in the upper Sacramento and the Willamette Rivers. The flood in the upper Sacramento was caused by torrential rains that began on November 15 and continued until late evening of November 20. The 24-hour rainfalls at Kennett, Calif., during this period were as follows:

	Inches.
16th	4.70
17th	6.50
18th	7.84
19th	4.34
20th	4.38
21st	2.85
Total	30.61

Below Kennett the rainfall did not average more than 6 inches. The river was at very low stage when the rains began, and flood warnings were issued on the 18th for Red Bluff and Tehama, Calif.

The crest stage at Red Bluff was 23.2 feet, 0.2 foot above the flood stage, at 5 a. m., November 19, with a proportionate rise at Tehama. The crest at Knights Landing, Calif., was 17.2 feet, 0.8 foot below the flood stage, at noon, November 22, and at Sacramento 22.8 feet, 6.2 feet below the flood stage, at 4 p. m., November 23.

Although but little water escaped over the levees along the lower river, local drainage caused considerable damage to the rice and bean crops, about 40 per cent of which had not been harvested. The value of property saved through the warnings, mainly in the shape of live stock, was not less than $50,000. A few cattle, sheep, and hogs were drowned.

The flood in the Willamette River was a local one, with flood stage at Eugene, Oreg., only, where the crest stage was 11.5 feet, 1.5 feet above the flood stage, on November 27. This flood was caused by almost persistent, although not very, heavy rains during the second and third decades of the month. No damage was reported.

MEAN LAKE LEVELS DURING NOVEMBER.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Dec. 3, 1920.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during November, 1920:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.48	580.30	571.95	245.23
Above or below—				
Mean stage of October, 1920	−0.20	−0.25	−0.10	−0.06
Mean stage of November, 1919	+0.03	−0.12	−0.27	−0.88
Average stage for November, last 10 years	−0.04	+0.02	+0.08	−0.41
Highest recorded November stage	−1.03	−2.62	−1.72	−2.59
Lowest recorded November stage	+0.98	+1.12	+1.25	+1.82
Average realtion of the November level to—				
October level	.....	−0.20	−0.30	−0.20
December level	.....	+0.20	+0.10	+0.20

[1] Lake St. Clair level: In November, 574.87 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS—NOVEMBER, 1920.

By J. WARREN SMITH, Meteorologist.

For the most part the weather during November, 1920, was favorable for outdoor operations, although work was delayed in portions of the South by considerable wet weather, while the low temperatures in central and northern States during the second decade were unfavorable for farm work. Rainfall was heavy in much of the Atlantic coast section the latter half of the month, but the weather was mostly fair throughout the month from the Mississippi Valley westward to the Rocky Mountains.

It was favorable for harvesting and drying corn in most of the principal corn-growing States and satisfactory progress was made in harvesting the crop. Considerable corn was reported soft and chaffy in some central Mississippi Valley districts.

Heavy rain in the eastern and northeastern portions of the cotton belt the latter part of the month delayed picking in that section, but otherwise the weather was mostly favorable for gathering cotton still in the field. Picking progressed slowly, however, in the northwestern portion of the belt, and the staple of the unpicked cotton steadily deteriorated on account of its exposure to the weather. Considerable low-grade cotton was abandoned in Texas.

Winter grains continued to make satisfactory progress throughout the month in nearly all sections of the country under the influence of generally favorable weather. At the close of the month winter wheat was in good to excellent condition and was steadily improving, although rain was needed in a few interior sections. The general

rains in southeastern States the latter half of the month were very favorable for winter grains, and wheat was greatly benefited in the lower Missouri Valley by the moisture received near its close.

Truck and miscellaneous crops, as well as pastures, ranges, and stock, continued generally in satisfactory condition, although some damage was done to sweet potatoes and truck in the Southern States by the freeze near the middle of the month. Ranges and pastures were benefited in the Pacific Coast States by the increased moisture received. Stock suffered considerably, however, in the Great Plains and Rocky Mountain States because of cold weather during the second decade, while, at the same time, deep snow in some central Rocky Mountain districts made range feed inaccessible.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, November, 1920.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	51.0	−2.9	Auburn	89	6	Florence	18	13†	3.03	+0.07	Milstead	5.32	Benton	0.70
Arizona	50.2	−1.1	Gila Bend	86	19	Lakeside	4	30	0.21	−0.75	Pinedale	2.08	28 stations	0.00
Arkansas	47.8	−3.9	Hope	89	7	Dutton	10	13	1.95	−1.47	El Dorado	5.78	Mountain Home	6.21
California	51.2	−1.7	Corona	87	14	Portola	9	2	5.34	+2.53	Branscomb	32.55	7 stations	0.00
Colorado	32.4	−2.4	Cheyenne Wells	78	20	Crested Butte	−24	29	0.64	−0.09	Silver Lake	3.50	4 stations	0.00
Florida	64.3	−1.1	3 stations	89	7	Mount Pleasant	25	18	4.06	+1.83	Titusville	6.92	Johnstown	1.48
Georgia	52.8	−1.6	Quitman	86	10	2 stations	18	13†	3.80	+1.12	Waycross	6.00	Americus	1.84
Hawaii (October)	73.7	+0.2	Mahukona	94	20	2 stations	51	22†	5.59	+0.70	Pepeekeo	21.62	3 stations	0.00
Idaho	35.3	−0.7	Springfield	64	18	Stanley	−10	28	2.60	+0.19	Alpha	6.39	Challis	0.21
Illinois	40.5	−1.3	Carbondale	78	6	2 stations	8	13	1.08	−1.44	Harrisburg	2.33	Hillsboro	0.34
Indiana	41.3	−0.8	2 stations	75	6	4 stations	9	13†	2.19	−1.04	Scottsburg	4.79	Terre Haute	0.61
Iowa	35.4	+0.4	2 stations	71	20	3 stations	5	11†	2.19	+0.68	Humboldt	4.45	Lamoni	0.73
Kansas	40.1	−4.4	2 stations	79	19	Leoti	−4	12	1.41	+0.19	Holton	3.59	Oakley	0.01
Kentucky	44.7	−1.4	2 stations	79	7	Anchorage	10	13	2.21	−1.14	Middlesboro	4.63	Blandville	0.92
Louisiana	54.3	−4.2	2 stations	88	8†	Calhoun	17	17	3.93	+0.55	Cheneyville	6.55	Melville	1.10
Maryland-Delaware	44.7	−0.2	4 stations	76	1	Oakland, Md.	3	14	4.09	+1.55	Seaford, Del.	7.88	Chesapeake City, Md.	2.69
Michigan	35.4	−0.5	Wasepi	69	21	Humboldt	−2	16	2.39	−0.24	Alpena (near)	3.96	Saint Joseph	0.57
Minnesota	29.7	−0.1	Canby	65	5	2 stations	−4	11†	1.18	+0.18	Winona	4.46	Alexandria	0.00
Mississippi	50.8	−4.2	Canton	88	6†	2 stations	17	17	3.27	−0.02	Anguilla	5.97	Collins	1.21
Missouri														
Montana	30.8	−1.3	2 stations	69	18†	Cascade	−28	12	0.50	−0.51	Belton	2.33	5 stations	T.
Nebraska	35.1	−1.4	Imperial	77	19	Harrison	−7	12	1.15	+0.42	Bradshaw	3.72	2 stations	0.00
Nevada	39.4	−1.1	Las Vegas	79	4	Lamoille	4	9	0.81	+0.04	Marlette Lake	4.70	Logandale	0.00
New England	35.1	−1.4	Waterbury, Conn.	78	2	Van Buren, Me.	−19	29	4.46	+1.09	Somerset, Vt.	9.41	Presque Isle	1.35
New Jersey	43.0	0.0	Bridgeton	74	1	Culvers Lake	11	13	4.41	+0.96	Long Branch	7.90	Trenton	2.14
New Mexico	41.4	−1.4	2 stations	82	20†	Elizabethtown	−3	3	0.24	−0.42	Pearl (near)	1.90	15 stations	0.00
New York	36.7	−0.8	3 stations	70	1	North Lake	1	13	4.07	+1.28	North Lake	6.66	Chazy	1.90
North Carolina	49.0	−0.1	Rockingham	83	10	2 stations	11	13	4.69	+2.33	Mount Airy	7.35	Banners Elk	2.70
North Dakota	28.0	+1.4	Steele	65	3†	Dunn Center	−14	9	0.37	−0.21	Langdon	1.10	3 stations	T.
Ohio	40.5	−0.8	Portsmouth	72	1	McArthur	5	18	2.82	+0.30	Piqua	5.29	Youngstown	1.43
Oklahoma	46.4	−4.2	Hobart	85	21	Oakwood	8	16	1.70	−0.29	Okeene	3.78	Tamaha	0.15
Oregon	40.5	−1.2	Florence	70	16	Blitzen	−10	7	4.44	−0.19	Agness	13.59	Umatilla	0.66
Pennsylvania	40.3	−0.5	Gettysburg	75	1	2 stations	5	14	3.54	+1.01	Waterville	6.42	New Castle	1.79
Porto Rico	77.0	−0.2	Jayuya	93	22†	Aibonito	57	26†	5.11	−2.50	Humacao	11.04	Coama	1.03
South Carolina	52.3	−1.5	Darlington	87	8	Landrum	18	14	3.62	+1.34	Gaston Shoals	6.99	Orangeburg	1.60
South Dakota	31.3	−0.5	2 stations	70	19	Spearfish	−14	12	0.98	+0.56	Centerville	2.37	Custer	T.
Tennessee	45.9	−2.4	4 stations	82	6†	Crossville (near)	10	18	2.89	−0.72	Jefferson City	4.70	Trenton	0.96
Texas	54.1	−2.9	Fort Stockton	96	20	Clint	9	29	2.66	+0.27	Houston	6.07	E. V. Ranch	0.00
Utah	36.5	−0.7	Riverdale	84	21	Black's Fork	−15	10	0.99	−0.12	Silver Lake	3.91	3 stations	0.00
Virginia	45.8	−0.4	3 stations	80	1†	Wise	3	17	5.27	+3.10	Blacksburg	7.84	Speers Ferry	1.86
Washington	40.6	+0.6	Washougal	73	18	2 stations	8	10	4.00	−1.16	Wind River	16.90	Lowden	0.45
West Virginia														
Wisconsin	32.6	−0.8	Wisconsin Rapids	68	20	Solon Springs	−6	12	2.31	+0.53	Baraboo	4.27	Winter	0.77
Wyoming	28.1	−3.7	Pine Bluff	69	19	Pinedale	−22	13	0.63	−0.10	Snake River	2.44	2 stations	0.00

* For description of tables and charts, see this REVIEW, January, 1920, p. 54.

† Other dates also.

TABLE 1.—*Climatological data for Weather Bureau Stations, November, 1920.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*									*0–10*	*In.*	*In.*
New England.							**38.4**	**– 0.6**											**76**	**4.14**	**+ 0.6**											**7.3**		
Eastport	76	67	85	29.99	30.08	+ .07	34.8	– 2.0	58	3	41	19	21	29	26	32	28	76	2.52	– 1.6	12	10,136	w.	61	ne.	23	5	10	15	6.7	8.6	0.5
Greenville, Me	1,070	6	....	28.90	30.10	.....	28.4	.....	48	5	35	– 5	29	22	34	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	6	23	.....	14.9	0.0
Portland, Me	103	82	117	30.00	30.12	+ .08	35.6	– 2.0	58	5	42	18	29	29	27	32	27	73	5.87	+ 2.1	14	7,248	n.	47	s.	3	10	5	15	5.9	15.2	4.3
Concord	288	70	79	29.79	30.11	+ .05	34.7	– 2.1	60	3	43	11	30	26	33	.....	.....	.....	.....	2.62	– 0.8	11	5,839	nw.	30	ne.	23	6	6	18	7.1	10.0	1.9
Burlington	404	11	48	29.66	30.12	+ .07	33.3	– 0.4	57	9	40	16	13	27	33	.....	.....	.....	.....	2.88	+ 0.3	13	7,430	s.	42	w.	12	0	6	24	9.0	12.7	5.4
Northfield	876	12	60	29.15	30.12	+ .07	30.9	– 1.1	58	9	38	8	30	24	37	29	26	81	4.20	+ 1.6	13	4,252	s.	29	sw.	12	0	2	28	9.4	22.5	14.6
Boston	125	115	188	29.96	30.10	+ .05	41.7	+ 0.5	64	2	48	22	13	35	27	37	33	72	5.46	+ 1.4	10	8,427	w.	59	ne.	23	5	8	17	7.5	1.8	0.0
Nantucket	12	14	90	30.07	30.08	+ .03	45.0	– 0.2	64	3	51	27	13	40	24	42	38	78	3.32	0.0	10	12,360	w.	69	sw.	3	4	8	18	7.2	0.0	0.0
Block Island	26	11	46	30.06	30.09	+ .03	44.2	– 1.1	63	2	49	26	13	39	20	41	38	79	3.44	– 0.4	9	14,942	nw.	70	e.	23	5	6	19	7.2	T.	0.0
Providence	160	215	251	29.93	30.11	+ .03	40.6	+ 1.1	62	3	47	22	13	34	25	37	33	76	3.69	– 0.2	12	9,492	nw.	49	w.	17	6	8	16	6.9	0.7	0.0
Hartford	159	122	140	29.94	30.12	+ .04	39.9	+ 0.4	62	2	46	21	13	33	25	36	31	73	6.43	+ 2.6	12	5,082	n.	44	sw.	2	5	7	18	7.4	T.	0.0
New Haven	106	74	153	30.00	30.13	+ .06	41.5	– 0.2	64	1	48	22	13	35	23	37	32	72	5.14	+ 1.6	12	7,110	ne.	40	sw.	2	9	7	14	6.3	T.	0.0
Middle Atlantic States.							**44.7**	**+ 0.6**											**77**	**4.33**	**+ 1.5**											**6.8**		
Albany	97	102	115	30.02	30.12	+ .04	38.2	– 0.2	58	10	44	18	13	32	27	35	32	80	4.44	+ 1.6	11	4,720	nw.	30	s.	9	5	7	18	7.5	2.6	0.0
Binghamton	871	10	84	29.15	30.10	+ .01	38.9	+ 1.3	59	9	44	21	13	34	26	.....	.....	.....	.....	3.24	+ 1.0	12	4,264	w.	27	w.	17	1	4	25	8.9	5.3	0.0
New York	314	414	454	29.77	30.12	+ .03	44.2	+ 0.2	67	1	50	25	13	38	19	40	34	70	3.56	+ 0.1	10	12,661	nw.	70	nw.	17	5	7	18	7.2	T.	0.0
Harrisburg	374	94	104	29.74	30.15	+ .04	43.1	+ 1.4	68	1	48	23	14	38	22	38	34	74	3.27	+ 0.9	10	4,490	w.	31	sw.	17	4	7	19	7.3	T.	0.0
Philadelphia	117	123	190	30.01	30.14	+ .04	46.0	+ 1.1	70	2	52	27	13	40	21	42	38	78	4.05	+ 1.0	10	7,639	nw.	46	ne.	16	6	5	19	7.3	0.0	0.0
Reading	325	81	98	29.78	30.14	.....	43.4	.....	67	1	49	24	14	38	22	39	34	75	3.13	0.0	11	4,742	nw.	40	e.	22	4	5	21	7.6	0.8	0.0
Scranton	805	111	119	29.24	30.13	+ .04	40.2	+ 1.1	59	1	45	21	13	35	23	37	34	84	2.97	+ 0.7	14	5,296	sw.	35	sw.	17	2	7	21	8.1	3.8	0.0
Atlantic City	52	37	48	30.07	30.13	+ .03	46.8	+ 1.3	71	1	53	24	13	41	20	43	39	78	6.00	+ 2.8	14	5,938	nw.	32	s.	2	12	3	15	6.0	0.0	0.0
Cape May	18	13	49	30.14	30.16	+ .06	47.8	+ 0.4	70	1	54	26	14	42	20	44	41	81	6.06	+ 2.8	13	6,429	nw.	42	ne.	16	10	4	16	6.3	0.0	0.0
Sandy Hook	22	10	55	30.10	30.12	.....	44.7	.....	64	1	49	28	13	40	16	42	39	83	3.60	.....	10	13,345	w.	66	ne.	17	5	9	16	7.0	T.	0.0
Trenton	190	159	183	29.91	30.12	.....	43.2	.....	67	2	50	23	13	37	23	39	35	75	2.14	– 1.3	11	7,775	ne.	52	ne.	17	7	4	19	6.9	T.	0.0
Baltimore	123	100	113	30.01	30.14	+ .03	47.1	+ 1.3	72	1	53	25	14	41	25	42	36	71	3.96	+ 1.0	10	4,449	sw.	32	ne.	17	8	5	17	6.6	T.	0.0
Washington	112	62	85	30.02	30.14	+ .02	45.9	+ 0.9	73	1	53	19	14	39	30	40	36	75	4.51	+ 1.8	11	4,896	nw.	42	nw.	17	7	5	18	6.9	T.	0.0
Lynchburg	681	153	188	29.39	30.15	+ .02	46.4	+ 0.3	79	1	56	15	14	37	36	40	36	74	7.14	+ 4.4	11	5,529	nw.	36	w.	17	12	7	11	5.2	0.0	0.0
Norfolk	91	170	205	30.04	30.14	+ .03	52.6	+ 1.4	75	9	61	31	13	45	33	46	41	73	3.64	+ 0.9	9	9,175	ne.	48	ne.	28	8	10	12	5.8	0.0	0.0
Richmond	144	11	52	29.99	30.14	+ .02	47.2	– 1.6	75	1	56	21	14	38	32	42	39	80	6.69	+ 4.3	9	5,199	ne.	42	sw.	17	9	8	13	5.9	0.0	0.0
Wytheville	2,304	49	56	27.74	30.18	+ .05	41.8	– 1.2	70	1	50	14	14	34	39	36	32	76	4.44	+ 1.4	11	4,812	w.	35	nw.	17	10	6	14	5.7	0.1	0.0
South Atlantic States.							**53.8**	**– 0.3**											**76**	**4.19**	**+ 1.4**											**4.8**		
Asheville	2,255	70	84	27.78	30.20	+ .04	44.2	– 0.9	76	1	54	18	14	34	36	38	34	76	3.15	– 0.2	8	5,702	nw.	38	e.	27	9	7	14	5.5	T.	0.0
Charlotte	779	55	62	29.30	30.15	+ .02	49.4	– 1.0	77	8	58	23	14	40	29	42	36	68	4.95	+ 2.1	7	3,845	ne.	22	nw.	17	15	7	8	4.5	0.0	0.0
Hatteras	11	12	50	30.10	30.11	.00	57.3	+ 0.6	75	2	63	41	18	51	21	55	50	81	3.53	– 1.1	9	11,027	w.	58	n.	28	10	8	12	5.5	0.0	0.0
Manteo	12	5	42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Raleigh	376	103	110	29.73	30.14	+ .01	50.2	0.0	76	8	59	26	13	41	28	43	38	69	6.72	+ 4.4	6	6,040	ne.	38	nw.	17	12	7	11	4.7	0.0	0.0
Wilmington	78	81	91	30.06	30.14	+ .02	55.2	+ 1.1	80	10	66	30	14	45	31	50	47	80	3.31	+ 0.9	9	5,184	w.	27	w.	17	16	4	10	4.4	0.0	0.0
Charleston	48	11	92	30.08	30.13	+ .01	57.4	– 0.7	80	10	66	36	14	49	25	52	49	81	3.07	+ 0.2	7	7,355	ne.	38	ne.	13	12	9	9	4.5	0.0	0.0
Columbia, S. C.	351	41	57	29.77	30.16	+ .04	52.4	– 1.4	79	10	62	29	14	43	32	45	39	68	3.26	+ 1.0	7	4,601	ne.	24	sw.	17	16	6	8	4.2	0.0	0.0
Greenville, S. C.	1,039	113	122	29.02	30.13	.....	50.1	.....	76	10	59	28	14	41	32	43	38	71	4.52	.....	8	5,963	ne.	36	w.	22	14	9	7	4.4	0.0	0.0
Augusta	180	62	77	29.94	30.14	+ .01	52.8	– 1.1	80	10	63	32	14	42	38	46	42	76	3.80	+ 0.9	5	3,446	nw.	22	sw.	2	15	3	12	4.9	0.0	0.0
Savannah	65	150	194	30.06	30.13	+ .01	57.8	+ 0.3	80	10	67	36	17	49	27	52	48	78	4.77	+ 2.4	7	8,056	ne.	37	nw.	16	12	7	11	5.2	0.0	0.0
Jacksonville	43	209	245	30.07	30.12	+ .02	61.6	+ 0.3	80	10	69	38	18	54	25	56	54	83	5.38	+ 3.2	7	8,811	n.	47	se.	27	15	3	12	4.8	0.0	0.0
Florida Peninsula.							**71.0**	**– 0.1**											**79**	**2.92**	**+ 0.7**											**6.2**		
Kew West	22	10	64	30.02	30.03	+ .03	74.5	+ 0.2	85	11	79	65	25	70	14	69	67	81	1.97	– 0.4	11	8,127	ne.	42	n.w.	16	10	4	16	6.1	0.0	0.0
Miami	25	71	79	30.03	30.06	.....	72.2	+ 0.2	82	10	78	54	24	66	22	67	64	77	3.73	+ 1.2	12	6,585	e.	27	e.	6	6	4	20	7.2	0.0	0.0
Sand Key	23	39	72	29.98	30.01	– .01	74.0	.....	84	3	77	66	18	71	12	69	67	78	2.73	.....	12	12,793	ne.	46	w.	16	9	8	13	5.8	0.0	0.0
Tampa	35	79	92	30.05	30.09	+ .01	66.2	– 0.6	84	6	75	42	18	58	27	60	57	80	3.07	+ 1.4	7	5,204	ne.	24	ne.	6	9	10	11	5.7	0.0	0.0
East Gulf States.							**53.3**	**– 2.5**											**73**	**3.13**	**– 0.4**											**4.8**		
Atlanta	1,174	190	216	28.90	30.16	+ .03	50.2	– 1.7	75	10	59	26	13	42	26	44	38	69	3.33	– 0.1	9	8,649	nw.	40	nw.	16	13	4	13	5.1	0.0	0.0
Leesburg	279	10	55	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Macon	370	78	87	29.75	30.15	+ .02	52.6	– 0.7	79	8	64	31	18	42	39	45	40	73	3.97	+ 0.9	6	4,201	nw.	24	ne.	16	12	7	11	4.8	0.0	0.0
Thomasville	273	49	58	29.83	30.13	+ .01	56.8	– 1.7	80	10	66	31	18	47	35	50	46	76	3.69	+ 1.0	7	3,129	ne.	18	sw.	28	15	3	12	4.9	0.0	0.0
Pensacola	56	149	185	30.09	30.15	+ .04	56.2	– 3.4	78	2	64	31	17	48	22	51	47	75	3.08	– 0.7	9	9,202	ne.	42	se.	27	15	4	11	5.0	0.0	0.0
Anniston	741	9	57	29.38	30.19	+ .07	49.1	– 2.8	77	9	61	26	17	37	40	.....	.....	.....	.....	4.30	+ 0.9	10	3,589	nw.	21	se.	27	12	9	9	4.7	0.0	0.0
Birmingham	700	11	48	29.41	30.20	+ .08	50.8	– 3.3	78	9	61	23	13	41	33	42	36	65	2.45	– 0.9	9	4,188	nw.	22	se.	29	14	7	9	4.5	0.0	0.0
Mobile	57	125	161	30.09	30.15	+ .04	56.2	– 1.3	80	7	66	31	17	46	30	50	45	75	1.68	– 2.1	9	7,298	n.	46	se.	27	17	6	7	3.9	0.0	0.0
Montgomery	223	100	112	29.92	30.18	+ .06	53.4	– 2.3	79	8	63	29	17	43	34	46	40	69	4.09	+ 1.0	6	4,390	n.	24	sw.	2	18	3	9	3.9	0.0	0.0
Corinth	469	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Meridian	375	85	93	29.77	30.18	+ .06	50.6	– 2.6	80	8	62	26	17	40	38	43	39	75	2.22	– 1.9	9	3,572	nw.	21	sw.	30	16	6	8	4.1	0.0	0.0
Vicksburg	247	65	73	29.92	30.21	+ .09	51.9	– 4.9	79	8	61	26	13	43	28	45	39	70	2.56	– 1.6	7	4,765	n.	25	e.	26	16	7	7	4.0	0.0	0.0
New Orleans	53	76	84	30.11	30.17	+ .07	58.2	– 2.4	79	8	66	36	13	50	23	52	49	80	3.03	– 0.8	6	4,724	ne.	23	ne.	12	15	7	8	4.4	0.0	0.0
West Gulf States.							**52.9**	**– 2.9**											**74**	**2.18**	**– 0.9**											**5.0**		
Shreveport	249	77	93	29.94	30.22	+ .11	52.2	– 2.6	81	1	62	27	16	42	30	45	40	72	2.15	– 1.9	8	5,068	se.	23	sw.	29	18	5	7	3.8	0.0	0.0
Bentonville	1,303	11	44	28.77	30.16	+ .05	43.2	– 3.5	72	5	52	13	16	34	34	.....	.....	.....	.....	0.93	– 2.1	8	3,957	s.	24	s.	20	11	9	10	5.3	T.	0.0
Fort Smith	457	79	94	29.69	30.18	+ .07	46.9	– 3.0	74	5	56	21	17	38	35	41	36	71	0.42	– 2.9	6	5,888	e.	34	sw.	29	11	8	11	5.4	T.	0.0
Little Rock	357	136	144	29.80	30.19	+ .07	48.4	– 3.1	76	7	58	23	13	39	35	43	38	72	0.88	– 3.7	7	6,119	s.	28	w.	22	16	2	12	4.6	T.	0.0
Brownsville	57	4	26	.....	.....	.....	64.5	.....	88	1	73	32	16	56	30	.....	.....	.....	2.42	.....	8	.....	n.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Corpus Christi	20	69	77	30.14	30.16	+ .09	61.6	– 1.8	83	1	68	33	16	56	29	57	54	81	1.84	– 0.6	7	7,761	n.	34	ne.	2	11	6	13	5.8	0.0	0.0
Dallas	512	109	117	29.63	30.19	.....	52.0	.....	76	8	61	22	16	43	33	.....	.....	.....	1.65	.....	6	5,755	nw.	29	s.	23	11	7	12	5.0	0.3	0.0
Fort Worth	670	106	114	29.46	30.18	+ .08	51.9	– 3.2	77	8	61	24	16	43	30	46	41	70	1.70	+ 0.1	5	6,647	nw.	28	w.	29	15	5	10	4.6	0.5	0.0
Galveston	54	106	114	30.13	30.19	+ .10	59.2	– 3.7	77	10	64	35	16	54	16	54	51	78	3.64	– 0.4	6	8,797	n.	38	n.	26	15	9	6	4.4	0.0	0.0
Groesbeck	461	11	56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Houston	138	111	121	30.02	30.17	.....	57.8	.....	82	9	66	29	16	50	26	.....	.....	.....	6.07	.....	7	6,200	se.	28	nw.	26	9	14	7	5.0	0.0	0.0
Palestine	510	64	72	29.66	30.20	+ .09	53.4	– 3.5	82	9	63	24	16	44	31	46	41	71	4.64	+ 1.0	4	4,963	n.	26	e.	26	12	8	10	5.5	0.0	0.0
Port Arthur	34	58	66	30.13	30.17	.....	56.4	.....	77	9	64	31	16	49	19	51	47	80	3.37	.....	6	6,502	e.	44	nw.	26	14	11	5	4.0	0.0	0.0
San Antonio	701	119	132	29.44	30.17	+ .09	57.4	– 1.8	84	9	66	27	16	49	31	51	45	70	2.95	+ 1.2	8	5,403	n.	26	nw.	28	7	11	12	6.0	0.0	0.0
Taylor	582	53	63	29.59	30.21	+ .13	54.7	– 3.0	82	1	64	25	16	45	34	.....	.....	.....	2.60	0.0	9	5,771	n.	26	ne.	26	8	11	11	5.8	T.	0.0

TABLE 1.—*Climatological data for Weather Bureau Stations, November, 1920*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.		°F.	°F.	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
							43.7	− 1.1											73	2.71	− 0.8										6.3		
Chattanooga	762	189	213	29.37	30.20	+ .06	47.4	− 2.9	76	8	57	24	13	38	34		41	36	71	3.08	− 0.5	12	4,777	w.	33	se.	29	12	6	12	5.3	0.1	0.0
Knoxville	996	102	111	29.10	30.18	+ .05	45.4	− 1.7	72	8	54	23	14	37	32		40	36	76	3.89	+ 0.3	11	3,916	sw.	24	ne.	27	10	7	13	5.7	T.	0.0
Memphis	399	76	97	29.79	30.23	+ .11	48.7	− 2.7	76	7	57	22	13	41	25		44	40	76	1.32	− 3.3	6	5,989	n.	30	nw.	21	18	2	10	4.2	0.0	0.0
Nashville	546	168	191	29.61	30.20	+ .08	46.7	− 2.0	74	7	56	21	13	38	33		40	35	68	2.60	− 1.2	9	6,347	w.	36	nw.	22	11	7	12	5.5	T.	0.0
Lexington	989	193	230	29.09	30.19	+ .07	43.3	− 1.4	71	6	50	18	13	36	28					2.22	− 1.3	9	9,191	sw.	35	w.	2	9	6	15	6.1	5.0	0.0
Louisville	525	219	255	29.60	30.19	+ .07	44.8	− 1.5	70	6	52	21	14	38	26		39	34	70	3.35	− 0.8	10	8,597	w.	36	nw.	11	13	2	15	5.5	1.5	3.0
Evansville	431	139	175	29.71	30.20	+ .08	44.7	− 0.6	72	6	52	18	13	37	27		39	33	70	1.38	− 2.7	7	7,605	sw.	29	nw.	11	10	7	13	5.7	T.	0.0
Indianapolis	822	194	230	29.25	30.16	+ .06	41.5	− 0.1	65	20	48	16	12	35	23		37	32	74	2.12	− 1.4	9	8,493	w.	32	w.	9	5	10	15	7.0	2.6	0.0
Royal Center	736	11	55	29.34	30.16	.....	39.0	.....	65	19	46	13	13	32	31		33	31	80	1.64	.....	12	7,080	w.	31	w.	9	5	6	19	7.3	0.1	0.0
Terra Haute	575	96	129	29.52	30.15	.....	42.2	.....	68	20	50	16	13	35	29		37	32	73	0.61	.....	5	6,806	nw.	28	nw.	9	6	14	10	6.2	T.	0.0
Cincinnati	628	11	51	29.48	30.17	+ .05	42.3	− 0.3	65	4	49	16	14	35	28				77	2.92	− 0.3	10	5,368	sw.	24	w.	2	7	6	17	6.7	5.4	0.0
Columbus	824	179	222	29.26	30.16	+ .05	40.6	− 0.8	61	9	47	17	13	34	26		38	35	82	3.45	+ 0.3	11	7,542	sw.	34	nw.	17	8	4	18	7.0	8.2	0.0
Dayton	899	181	216	29.14	30.12	.....	41.4	− 0.7	64	6	48	17	13	35	25		38	34	78	3.46	+ 0.6	14	7,384	sw.	28	w.	2	6	7	17	6.8	8.6	0.0
Elkins	1,947	59	67	.....	30.19	+ .07	39.3	− 0.3	70	1	48	8	14	31	36					3.71	+ 0.8	13	3,628	w.	28	w.	17	8	5	17	.....	3.9	0.0
Parkersburg	638	77	84	29.50	30.18	+ .06	43.0	− 0.2	68	1	50	15	14	36	26		38	34	75	1.82	− 1.0	11	3,669	sw.	24	w.	2	7	5	18	7.2	2.7	0.0
Pittsburgh	842	353	410	29.22	30.14	+ .04	42.2	− 0.7	67	1	47	19	13	37	24		38	34	75	2.57	0.0	12	8,449	sw.	38	w.	17	5	6	19	7.6	3.4	0.0
Lower Lake Region.							38.7	− 0.5											78	3.59	+ 0.6										8.2		
Buffalo	767	247	280	29.25	30.10	+ .05	38.4	− 0.9	57	9	43	23	12	34	23		35	32	79	4.30	+ 1.0	14	12,806	w.	72	sw.	2	0	3	27	9.2	15.8	0.0
Canton	448	10	61	29.59	30.08	.....	32.0	− 1.9	57	9	38	12	13	26	27					4.45	+ 1.0	13	8,373	e.	37	e.	17	0	6	24	9.0	19.5	8.0
Oswego	335	76	91	29.72	30.10	+ .05	37.9	− 1.2	60	9	43	23	12	33	22		35	32	82	5.69	+ 2.3	17	8,449	s.	34	nw.	12	1	4	25	8.8	8.0	0.0
Rochester	523	86	102	29.53	30.12	+ .07	38.0	+ 0.1	62	9	43	22	13	34	22		34	31	76	4.06	+ 1.2	16	6,262	w.	31	w.	12	0	6	24	9.0	12.4	0.0
Syracuse	597	97	113	29.45	30.11	+ .05	37.4	− 1.3	60	9	42	21	12	33	22					4.24	+ 1.5	18	7,701	w.	40	w.	12	0	5	25	9.1	5.4	0.0
Erie	714	130	166	29.32	30.11	+ .05	40.8	− 0.3	61	9	45	24	14	36	20		37	33	75	3.72	+ 0.1	16	10,187	sw.	41	se.	22	3	4	23	8.4	8.7	0.0
Cleveland	762	190	201	29.28	30.12	+ .05	41.2	+ 0.8	65	9	46	20	13	36	25		37	33	74	2.25	− 0.5	12	9,295	sw.	44	nw.	17	4	8	18	7.4	3.5	0.0
Sandusky	629	62	103	29.42	30.12	+ .04	41.0	+ 0.2	64	9	46	19	13	36	26					2.24	− 0.5	11	9,015	sw.	44	ne.	16	4	7	19	7.4	3.6	0.0
Toledo	628	208	243	29.43	30.13	+ .06	40.5	+ 0.8	63	9	47	19	13	34	26		37	33	78	2.69	0.0	11	9,431	sw.	43	w.	9	6	8	16	6.8	6.1	0.0
Fort Wayne	856	113	124	29.19	30.14	.....	39.7	− 0.9	63	20	46	15	13	33	25		36	32	79	2.42	.....	14	6,785	sw.	34	w.	4	4	8	18	7.5	4.4	0.0
Detroit	730	218	245	29.31	30.12	+ .06	39.1	− 0.5	60	9	45	18	13	34	24		36	33	81	2.29	− 0.3	14	8,674	w.	44	w.	9	4	8	18	7.4	5.4	0.0
Upper Lake Region.							35.3	+ 0.9											82	2.09	− 0.4										8.0		
Alpena	609	13	92	29.42	30.10	+ .09	35.1	+ 1.4	56	4	40	10	12	30	23		33	31	87	3.88	+ 1.3	15	8,298	w.	42	e.	21	0	8	22	8.6	4.6	0.0
Escanaba	612	54	60	29.42	30.11	+ .08	33.0	+ 1.3	50	4	38	13	13	28	22		30	27	82	1.53	− 0.7	12	6,736	nw.	29	ne.	2	5	7	18	6.9	3.9	T.
Grand Haven	632	54	89	29.40	30.10	+ .06	38.9	+ 0.9	56	1	43	21	11	34	20		37	34	83	1.84	− 0.7	14	8,399	w.	51	nw.	9	2	7	21	8.4	10.4	0.0
Grand Rapids	707	70	87	29.32	30.11	+ .06	38.2	+ 0.1	55	4	43	18	12	33	21		35	32	80	1.54	− 1.0	13	3,999	w.	26	w.	9	1	6	23	8.8	6.5	0.0
Houghton	684	62	99	29.35	30.10	+ .08	32.2	+ 0.7	47	6	36	16	16	28	18					3.41	− 0.6	16	6,959	w.	38	w.	12	1	5	24	8.6	20.5	T.
Lansing	878	11	62	29.14	30.10	.....	36.6	− 0.2	57	4	43	14	16	30	24		34	32	87	2.29	− 0.1	17	4,093	sw.	25	sw.	9	1	7	22	8.4	4.0	0.0
Ludington	637	60	66	29.38	30.09	.....	37.8	.....	53	4	42	21	11	33	21		35	32	80	2.29	.....	17	7,878	w.	36	w.	9	1	12	17	7.7	8.1	0.0
Marquette	734	77	111	29.30	30.12	+ .10	33.8	+ 1.9	50	8	39	16	11	29	23		30	28	83	2.96	+ 0.2	13	6,762	w.	31	sw.	12	4	4	22	8.1	17.5	0.1
Port Huron	638	70	120	29.39	30.10	+ .05	37.4	+ 0.6	58	9	43	17	12	32	24		35	32	85	1.87	− 0.8	12	7,904	sw.	41	w.	9	0	11	19	7.9	3.2	0.0
Saginaw	641	69	77	29.40	30.11	.....	36.6	.....	57	4	42	16	12	31	22		34	32	87	1.61	− 0.7	12	6,017	sw.	28	sw.	9	1	9	20	8.2	0.9	0.0
Sault Ste. Marie	614	11	52	29.39	30.10	+ .09	32.6	+ 1.9	51	4	37	11	12	28	20		30	27	82	1.68	− 1.2	13	5,823	se.	30	nw.	4	0	2	28	9.6	7.5	0.0
Chicago	823	140	310	29.22	30.13	+ .06	40.2	+ 1.0	64	20	46	16	12	34	23		36	32	73	0.92	− 1.6	9	8,437	nw.	31	w.	4	6	7	17	6.8	1.3	0.0
Green Bay	617	109	144	29.42	30.10	+ .06	34.4	+ 1.9	53	4	40	14	12	29	21		31	27	78	3.48	+ 1.5	11	7,745	sw.	46	w.	4	7	3	20	7.4	0.7	0.0
Milwaukee	681	125	139	29.35	30.10	+ .05	37.6	+ 1.5	57	4	43	15	12	32	21		34	30	75	0.81	− 1.2	11	7,173	w.	31	se.	6	7	4	19	7.3	0.4	0.0
Duluth	1,133	11	47	28.86	30.13	+ .09	28.4	− 0.9	48	19	34	5	11	23	23		26	24	87	1.40	− 0.2	10	9,745	sw.	42	nw.	11	5	10	15	6.6	11.6	T.
North Dakota.							28.5	+ 3.9											80	0.38	− 0.4										6.5		
Moorhead	940	8	57	29.11	30.16	+ .09	29.3	+ 4.9	56	3	36	5	15	22	31		26	24	84	0.29	− 0.7	4	5,641	n.	27	n.	9	5	4	21	7.6	0.4	0.0
Bismarck	1,674	8	57	28.34	30.20	+ .13	29.6	+ 3.6	61	3	39	0	13	20	35		25	21	76	0.39	− 0.3	3	5,907	nw.	33	nw.	3	8	10	12	5.7	T.	0.0
Devils Lake	1,482	11	44	28.50	30.12	+ .06	27.2	+ 4.6	56	3	36	2	11	19	30		24	21	82	0.76	0.0	8	6,772	nw.	44	n.	8	6	7	17	6.6	5.8	3.1
Ellendale	1,457	10	56	28.55	30.16	.....	28.9	.....	59	3	37	2	13	21	32		26	23	82	0.42	.....	2	9,660	nw.	48	n.	9	5	7	18	7.0	0.2	0.0
Grand Forks	835	12	89	.....	.....	.....	27.6	.....	54	3	35	6	9	20	32		25	.....		0.98	.....	8	.....	nw.	53	nw.	4	8	5	17	.....	1.3	0.0
Williston	1,878	41	48	28.09	30.14	+ .08	27.8	+ 2.6	54	3	37	− 3	9	18	31		24	20	74	0.09	− 0.5	5	4,927	w.	40	w.	3	9	8	13	5.8	0.5	T.
Upper Mississippi Valley.							37.8	+ 0.1											77	1.45	− 0.6										6.7		
Minneapolis	918	102	208	29.10	30.10	.....	33.1	.....	53	5	38	9	11	28	29		.....	.....	.....	1.24	+ 0.1	8	8,151	nw.	37	w.	4	6	5	19	7.2	1.1	0.0
St. Paul	837	236	261	29.20	30.13	+ .07	32.6	+ 1.7	52	5	38	11	11	27	29		.....	.....	.....	1.08	− 0.2	5	8,470	nw.	46	sw.	4	5	8	17	7.0	2.3	0.0
La Crosse	714	11	48	29.32	30.11	+ .04	34.2	+ 0.4	54	4	40	12	16	28	25		.....	.....	.....	2.85	+ 1.3	8	3,470	nw.	19	nw.	11	6	2	22	7.6	3.2	0.0
Madison	974	70	78	29.05	30.14	+ .08	34.2	− 0.0	55	4	40	12	12	29	24	32	30	85	1.83	0.0	7	6,352	nw.	28	w.	4	5	4	21	7.6	0.5	0.0
Wausau	1,247	4	.....	28.72	30.10	.....	31.3	.....	51	19	37	10	12	26	28		.....	.....	.....	2.31	.....	10	.....	nw.	.....	.....	.....	5	5	20	7.8	6.3	T.
Charles City	1,015	10	49	29.03	30.14	+ .06	33.5	+ 0.5	54	19	40	10	12	26	29	30	27	81	2.73	+ 1.3	10	4,753	nw.	22	nw.	11	5	8	17	7.3	3.7	0.0
Davenport	606	71	79	29.47	30.15	+ .07	37.8	+ 0.3	66	20	45	12	12	31	25	34	30	78	1.69	− 0.1	7	4,838	nw.	22	w.	21	9	4	17	6.6	0.4	0.0
Des Moines	861	84	97	29.20	30.13	+ .05	37.6	+ 0.8	67	19	45	12	13	30	28	34	30	80	1.63	+ 0.2	11	5,124	sw.	22	nw.	9	8	8	14	6.3	0.8	0.0
Dubuque	698	81	96	29.38	30.16	+ .09	35.6	− 0.4	61	20	42	13	12	29	27	33	29	80	2.01	+ 0.2	10	4,159	nw.	22	nw.	11	4	8	18	7.4	1.4	0.0
Keokuk	614	64	78	29.47	30.17	+ .08	39.2	− 0.2	68	20	47	12	12	32	29	35	30	71	0.98	− 0.9	9	5,447	w.	29	w.	2	9	4	17	6.5	T.	0.0
Cairo	356	87	93	29.79	30.19	+ .07	44.5	− 2.4	73	6	52	19	13	37	29	39	34	70	0.79	− 3.3	6	6,421	n.	33	n.	12	11	4	15	5.6	T.	0.0
Peoria	609	11	45	29.47	30.16	+ .07	38.6	+ 1.1	67	20	46	13	12	31	30	34	32	82	1.22	− 1.4	7	4,821	s.	22	w.	2	8	6	16	6.4	0.5	0.0
Springfield, Ill	644	10	91	29.46	30.15	+ .05	40.0	− 0.7	68	20	47	16	12	33	25	35	31	76	0.79	− 1.9	6	5,905	w.	22	nw.	9	7	9	14	6.4	0.4	0.0
Hannibal	534	74	109	29.57	30.16	+ .07	40.0	− 0.5	71	20	48	13	13	32	29	.....	.....	.....	0.95	− 1.0	8	6,143	sw.	27	sw.	1	10	6	14	6.1	T.	0.0
St. Louis	567	265	303	29.55	30.17	+ .07	43.7	+ 0.3	72	20	51	19	12	36	27	37	31	65	0.56	− 2.3	5	9,207	nw.	36	s.	20	10	9	11	5.3	T.	0.0
Missouri Valley.							37.0	− 0.4											78	1.13	− 0.1										6.3		
Columbia, Mo	781	11	84	29.30	30.16	+ .07	40.8	− 1.6	72	20	50	11	13	32	31	.....	.....	.....	.....	0.63	− 1.7	7	5,716	s.	27	sw.	1	12	6	12	5.3	0.3	0.0
Kansas City	963	161	181	29.11	30.17	+ .08	41.4	− 0.1	71	19	49	16	12	34	29	36	31	71	1.73	− 0.1	8	8,103	nw.	33	nw.	21	10	7	13	5.9	T.	0.0
St. Joseph	967	11	49	29.09	30.15	.....	39.6	.....	70	19	47	14	12	32	29	35	31	75	2.75	.....	8	6,175	nw.	35	nw.	1	9	6	15	6.3	T.	0.0
Springfield, Mo	1,324	98	104	28.74	30.18	+ .08	41.6	− 2.8	70	6	50	14	13	34	28	37	33	75	0.64	− 2.0	6	7,426	s.	30	s.	20	11	8	11	5.2	T.	0.0
Iola	984	11	50	29.09	30.17	+ .08	41.6	− 1.4	72	5	50	13	13	33	41	.....	.....	.....	.....	1.35	0.0	8	4,880	s.	22	nw.	21	6	9	15	6.7	T.	0.0
Topeka	987	92	107	.....	.....	.....	40.4	− 1.3	70	19	48	14	13	32	37	.....	.....	.....	.....	2.05	+ 0.8	6	7,381	s.	31	n.	11	8	6	16	6.8	T.	0.0
Drexel	1,299	10	53	28.72	30.14	.....	35.1	.....	63	19	43	12	12	28	36	32	29	85	2.50	.....	9	7,505	nw.	30	nw.	1	8	5	17	6.7	1.9	0.0
Lincoln	1,189	11	84	28.86	30.16	+ .08	37.0	− 1.0	68	19	44	13	12	29	33	38	29	78	1.20	+ 0.4	7	6,976	n.	36	nw.	1	4	8	18	7.4	2.0	T.
Omaha	1,105	115	122	28.95	30.17	+ .09	37.2	− 0.5	68	19	44	14	12	30	31	33	30	78	1.47	+ 0.4	9	6,144	nw.	30	nw.	11	9	6	15	6.4	0.4	0.0
Valentine	2,598	47	54	27.39	30.20	+ .12	32.2	− 1.5	69	19	42	3	15	22	36	27	24	78	0.46	− 0.3	7	6,953	nw.	35	nw.	1	12	9	9	5.0	4.4	0.0
Sioux City	1,135	94	164	28.91	30.17	+ .09	34.4	+ 0.1	60	19	42	11	11	27	30	31	28	80	1.46	+ 0.5	9	8,552	nw.	54	nw.	1	6	5	19	7.3	0.4	0.0
Huron	1,306	59	74	28.74	30.19	+ .11	30.4	+ 3.0	56	18	38	7	13	25	30	27	24	81	0.92	+ 0.3	5	6,968	nw.	36	n.	1	7	9	14	6.4	6.5	0.0
Pierre	1,572	70	75	28.46	30.19	+ .11	32.2	+ 0.6	60	18	40	10	13	24	33	28	25	81	0.71	+ 0.3	5	5,671	nw.	33	nw.	1	8	5	17	6.4	7.2	0.0
Yankton	1,233	49	57	28.80	30.16	+ .08	34.2	+ 1.7	64	18	42	12	11	26	39	.....	.....	.....	.....	0.95	+ 0.2	8	5,988	nw.	35	nw.	1	7	6	17	6.9	1.5	0.0

TABLE 1.—*Climatological data for Weather Bureau Stations, November, 1920*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.					
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
Northern Slope.							30.2	— 1.9										76	0.52	— 0.3									5.1		
Billings	3,140	5																													
Havre	2,505	11	44	27.44	30.15	+ .12	33.6	+ 3.0	60	19	45	— 3	14	22	35	28	24	75	0.07	— 0.7	1	5,924	sw.	44	w.	3	16	10	4	3.7	0.7	0.0
Helena	4,110	87	112	25.89	30.22	+ .12	30.9	— 1.8	55	18	39	— 7	12	23	25	26	20	67	0.34	— 0.4	4	4,748	sw.	38	sw.	27	7	7	16	6.3	4.8	0.0
Kalispell	2,973	48	56	.....	30.17	+ .10	32.6	+ 0.6	51	19	40	4	12	26	26	.....	.....	.....	0.43	— 1.5	7	3,002	nw.	28	sw.	3	8	5	17	....	0.1	0.0
Miles City	2,371	26	48																												
Rapid City	3,259	50	58	26.69	30.23	+ .15	33.5	— 0.1	70	19	44	0	12	22	47	26	19	59	0.42	0.0	3	5,889	w.	36	nw.	9	13	6	11	4.8	4.2	0.0
Cheyenne	6,088	84	101	24.05	30.20	+ .13	31.8	— 3.1	62	19	41	— 1	12	23	27	26	20	66	0.22	— 0.2	3	9,775	w.	46	w.	27	16	5	9	4.5	4.1	0.0
Lander	5,372	60	68	24.74	30.36	+ .26	18.8	— 9.9	49	19	29	—15	10	8	30	14	7	66	1.50	+ 0.9	5	1,852	sw.	25	se.	27	15	11	4	4.2	16.7	0.0
Sheridan	3,790	10	47	26.19	30.24	.....	28.3	.....	56	19	40	—11	12	16	38	23	19	70	0.49	.....	7	3,195	nw.	32	nw.	8	13	9	8	5.1	5.4	0.0
Yellowstone Park	6,200	11	48	23.94	30.26	+ .15	26.2	— 3.1	49	19	35	— 8	12	18	37	23	19	75	1.13	— 0.3	15	5,310	s.	35	sw.	3	3	13	14	6.8	10.4	1.0
North Platte	2,821	11	51	27.20	30.23	+ .15	34.6	— 0.5	72	19	46	4	15	23	42	28	23	72	0.04	— 0.4	3	5,076	w.	32	n.	28	11	9	10	5.1	0.4	0.0
Middle Slope.							39.7	— 2.0										76	1.28	— 0.3									4.8		
Denver	5,292	106	113	24.80	30.19	+ .13	36.7	— 2.5	70	19	47	10	12	27	36	30	23	63	0.08	— 0.4	3	4,967	s.	32	n.	28	16	6	8	4.0	5.6	0.0
Pueblo	4,685	80	86	25.38	30.17	+ .12	37.8	— 1.5	74	19	50	12	12	26	46	31	24	64	0.28	— 0.1	4	3,708	nw.	35	nw.	20	15	7	8	4.5	2.6	0.0
Concordia	1,392	50	58	28.68	30.20	+ .12	38.2	— 1.7	70	18	46	14	12	30	41	34	31	82	1.47	+ 0.5	7	5,981	nw.	30	nw.	21	6	7	17	6.9	4.3	0.3
Dodge City	2,509	11	51	27.54	30.21	+ .14	39.4	— 1.1	74	20	50	12	12	29	39	33	30	78	1.13	+ 0.6	5	7,240	nw.	32	nw.	28	18	3	9	3.9	0.8	0.0
Wichita	1,358	139	158	28.71	30.18	+ .10	40.9	— 2.9	68	5	48	16	13	34	28	37	34	80	2.68	+ 1.5	6	9,346	s.	38	n.	29	12	8	10	5.0	T.	0.0
Altus	1,410	5					47.4	.....	77	20	58	18	16	37	39				2.35	.....	7	.....	n.	.....	.....	.....	15	1	14	.....	T.	0.0
Broken Arrow	765	11	52	29.34	30.18	.....	43.5	.....	73	5	52	17	16	35	34	40	37	83	1.10	.....	9	8,708	s.	41	s.	20	14	6	10	4.9	0.0	0.0
Muskogee	652	4					47.2	.....	78	4	58	18	16	37	40				0.79	.....	8	.....	e.	.....	.....	.....	17	7	6	.....	0.0	0.0
Oklahoma	1,214	10	47	28.88	30.19	+ .11	45.2	— 2.7	74	20	54	18	16	36	30	40	36	79	2.04	— 0.2	7	9,562	s.	37	s.	20	14	7	9	4.7	0.2	0.0
Southern Slope.							48.8	— 2.1										69	0.98	— 0.2									4.4		
Abilene	1,738	10	52	28.34	30.19	+ .12	49.4	— 3.2	75	20	59	19	16	39	34	43	38	72	1.92	+ 0.7	8	6,178	s.	32	s.	20	16	2	12	4.6	0.4	0.0
Amarillo	3,676	10	49	26.37	30.17	+ .12	42.8	— 1.0	78	20	54	17	13	31	41	36	31	73	1.33	+ 0.2	6	7,047	sw.	30	nw.	28	17	6	7	4.3	2.6	0.0
Del Rio	944	64	71	29.15	30.15	+ .10	57.2	— 2.1	80	1	66	30	16	48	35	.....	.....	.....	0.52	— 0.7	8	5,910	se.	39	nw.	28	12	6	12	5.5	0.0	0.0
Roswell	3,566	75	85	26.46	30.13	+ .10	45.9	— 2.2	76	19	60	17	29	32	45	38	30	63	0.15	— 1.0	3	4,328	s.	31	nw.	28	18	7	5	3.4	T.	0.0
Southern Plateau.							50.7	— 1.1										55	0.04	— 0.5									2.9		
El Paso	3,762	110	133	26.28	30.08	+ .08	51.6	+ 0.7	75	5	64	24	29	40	35	42	32	53	T.	— 0.6	0	6,249	nw.	39	w.	25	19	7	4	2.9	0.0	0.0
Santa Fe	7,013	57	66	23.29	30.13	+ .10	37.7	— 0.5	64	19	48	14	29	28	30	29	23	63	0.14	— 0.6	5	5,539	n.	30	n.	27	17	6	7	3.6	1.4	0.0
Flagstaff	6,908	10	59																												
Phoenix	1,108	76	81	28.86	30.03	+ .05	58.6	— 0.1	79	18	75	33	30	43	44	47	38	57	T.	— 1.0	0	2,925	e.	18	s.	6	19	4	7	3.2	0.0	0.0
Yuma	141	9	54	29.90	30.05	+ .07	60.5	— 1.4	82	19	75	40	25	46	35	48	38	53	0.00	— 0.3	0	3,052	n.	19	n.	2	27	2	1	1.0	0.0	0.0
Independence	3,957	9	41	26.05	30.14	+ .09	45.0	— 4.2	69	19	58	23	6	32	35	35	23	47	0.07	— 0.2	3	3,285	nw.	33	w.	19	16	11	3	3.6	T.	0.0
Middle Plateau.							38.9	— 0.7										67	0.85	— 0.2									5.4		
Reno	4,532	74	81	25.51	30.12	+ .01	40.8	— 0.2	65	17	51	21	2	31	38	35	29	68	0.72	— 0.4	6	3,821	w.	48	se.	19	7	11	12	5.7	3.3	0.0
Tonopah	6,090	12	20	24.13	30.14	.....	38.9	.....	57	3	46	19	6	32	19	32	24	58	0.39	— 0.5	3	5,963	se.	33	nw.	27	9	14	7	5.0	2.3	0.0
Winnemucca	4,344	18	56	25.69	30.16	+ .02	37.6	— 0.1	59	26	48	14	2	27	42	32	28	73	1.33	— 0.6	10	4,583	ne.	32	sw.	26	8	7	15	6.6	1.4	0.0
Modena	5,479	10	43	24.68	30.13	+ .05	36.1	— 2.9	61	17	49	10	3	23	38	29	23	66	0.10	— 0.5	2	5,489	w.	35	s.	5	14	12	4	3.9	0.1	0.0
Salt Lake City	4,360	163	203	25.72	30.17	+ .05	40.4	0.0	65	18	47	23	29	34	25	35	30	70	1.90	+ 0.5	11	3,933	nw.	34	nw.	27	6	8	16	6.5	3.0	T.
Grand Junction	4,602	60	68	25.49	30.14	+ .06	39.8	— 0.1	59	20	50	20	28	30	30	34	28	69	0.67	+ 0.1	5	3,127	se.	28	se.	5	11	8	11	4.9	T.	0.0
Northern Plateau.							39.1	+ 0.5										73	1.36	0.0									6.7		
Baker	3,471	48	53	26.52	30.17	+ .01	36.4	+ 1.5	55	18	44	14	11	29	26	33	28	72	0.53	— 0.6	9	4,558	se.	28	se.	21	10	3	17	6.4	T.	0.0
Boise	2,739	78	86	27.28	30.19	+ .02	40.8	+ 1.2	60	18	48	22	5	33	25	37	33	74	1.82	+ 1.0	10	3,562	se.	24	se.	21	8	7	15	6.5	2.4	0.0
Lewiston	757	40	48	29.33	30.15	+ .03	41.4	+ 0.5	59	20	50	22	7	33	26	.....	.....	.....	1.09	— 0.2	9	2,155	e.	20	nw.	3	5	9	16	6.9	0.0	0.0
Pocatello	4,477	60	68	25.58	30.20	+ .06	35.4	— 0.9	58	18	42	12	10	28	23	31	27	74	1.29	+ 0.7	11	5,766	se.	36	sw.	27	6	10	14	6.8	4.9	0.0
Spokane	1,929	101	110	28.06	30.16	+ .08	38.9	+ 1.6	56	18	46	17	10	32	29	35	30	72	1.30	— 1.0	10	4,529	s.	37	sw.	26	5	8	17	7.1	T.	0.0
Walla Walla	991	57	65	29.04	30.14	+ .01	41.8	— 1.1	67	18	49	26	6	34	27	37	33	72	2.10	0.0	10	3,130	s.	27	sw.	26	9	4	17	6.3	0.1	0.0
North Pacific Coast Region.							47.1	+ 1.5										81	5.80	— 1.0									7.1		
North Head	211	11	56	29.78	30.01	— .04	49.0	+ 1.3	60	30	53	38	12	45	15	45	40	74	5.03	— 1.3	15	13,291	se.	68	s.	26	9	2	19	6.6	0.0	0.0
Port Angeles	29	8	53	30.00	30.03	.....	43.8	.....	57	16	50	30	11	37	22	.....	.....	.....	2.67	— 1.8	14	3,659	s.	36	sw.	27	3	4	23	8.0	0.0	0.0
Seattle	125	215	250	29.92	30.06	+ .02	47.0	+ 2.5	59	18	52	32	10	41	22	43	40	78	4.42	— 1.4	11	6,657	se.	60	s.	26	7	7	16	7.0	0.0	0.0
Tacoma	213	113	120	29.84	30.07	+ .03	46.1	+ 2.0	61	18	52	30	9	40	25	44	42	88	4.08	— 4.4	14	4,049	s.	42	sw.	26	4	9	17	7.1	0.0	0.0
Tatoosh Island	86	7	57	29.87	29.97	.00	48.1	+ 2.2	54	16	51	42	12	45	9	45	42	83	12.26	+ 0.2	21	15,438	e.	93	s.	26	8	1	21	7.3	0.0	0.0
Yakima	1,071	4					39.1	.....	59	7	49	14	10	29	35	.....	.....	.....	1.35	.....	7	.....	w.	.....	.....	.....	7	9	14	.....	T.	0.0
Medford	1,425	4																													
Portland, Oreg	153	68	106	29.91	30.07	— .03	46.8	+ 1.2	61	17	53	34	5	41	20	43	38	76	5.84	— 0.6	16	4,470	se.	32	w.	26	7	4	19	7.0	T.	0.0
Roseburg	510	9	57	29.52	30.08	— .04	45.6	0.0	62	17	53	27	10	38	31	43	41	87	6.27	+ 1.9	15	1,634	s.	23	w.	26	4	13	13	6.8	0.0	0.0
Middle Pacific Coast Region.							51.6	— 1.4										78	4.47	+ 1.3									6.1		
Eureka	62	73	80	30.02	30.09	— .02	51.2	+ 0.2	64	20	58	35	6	45	19	49	47	84	6.35	+ 0.7	16	4,155	se.	34	se.	21	7	8	15	6.6	0.0	0.0
Mount Tamalpais	2,375	11	18	27.60	30.10	+ .01	47.1	— 3.5	60	29	51	35	7	43	17	.....	.....	.....	5.74	+ 2.1	13	13,279	se.	66	nw.	4	7	6	17	6.7	0.0	0.0
Point Reyes Light	490	7	18	29.53	30.05	.....	52.6	— 0.4	65	29	56	44	7	49	15	.....	.....	.....	3.24	.....	13	14,964	s.	70	s.	15	9	8	13	5.9	0.0	0.0
Red Bluff	332	50	56	29.74	30.10	— .01	51.2	— 2.2	71	3	59	32	10	43	34	46	41	72	6.79	+ 3.6	13	4,903	nw.	31	n.	5	8	8	14	6.2	0.0	0.0
Sacramento	60	106	117	30.04	30.11	+ .02	51.0	— 2.4	70	3	59	35	6	44	32	48	44	79	3.39	+ 1.2	11	4,766	se.	31	se.	15	12	8	10	5.4	0.0	0.0
San Francisco	155	208	243	29.93	30.10	+ .01	55.4	— 0.1	69	3	60	45	6	50	20	51	47	77	2.70	+ 0.2	12	5,253	se.	27	se.	15	9	6	15	6.2	0.0	0.0
San Jose	141	12	110	29.96	30.11	.....	53.0	— 1.4	72	3	63	33	5	43	36	.....	.....	.....	1.84	0.0	14	4,121	se.	34	se.	15	9	6	15	5.8	0.0	0.0
South Pacific Coast Region.							57.1	— 0.4										72	0.99	— 0.1									3.9		
Fresno	327	89	98	29.76	30.12	+ .06	54.0	— 0.6	72	18	64	37	25	44	28	48	43	71	0.99	0.0	5	3,777	nw.	25	se.	19	13	13	4	3.9	0.0	0.0
Los Angeles	338	159	191	29.72	30.09	+ .07	60.1	— 0.2	80	14	69	46	6	52	26	52	46	69	1.15	+ 0.3	3	3,744	ne.	19	nw.	6	14	10	6	4.1	0.0	0.0
San Diego	87	62	70	29.98	30.07	+ .05	58.2	— 0.8	74	29	66	46	1	51	25	53	49	77	0.19	— 0.6	4	3,901	nw.	22	nw.	8	15	11	4	3.6	0.0	0.0
San Luis Obispo	201	32	40	29.89	30.11	+ .05	56.2	—0.1	80	3	67	31	1	45	43	48	43	70	1.64	— 0.1	7	2,328	n.	26	ne.	28	12	10	8	4.0	0.0	0.0
West Indies.																															
San Juan, P. R	82	8	54	29.89	29.97	.....	77.9	.....	84	25	83	72	29	73	12	.....	.....	.....	5.22	— 1.7	20	7,280	e.	40	ne.	9	10	17	3	4.2	0.0	0.0
Panama Canal.																															
Balboa Heights	118	7	97	29.72	29.84	.00	79.6	+ 0.6	92	30	86	71	18	74	16	75	74	86	19.22	+ 8.7	21	4,586	nw.	27	ne.	11	0	10	20	7.8	0.0	0.0
Colon	36	7	97	29.80	29.84	— .01	81.0	+ 2.0	91	10	86	72	7	76	16	76	75	82	21.27	+ 0.2	22	6,506	w.	28	ne.	7	1	15	14	7.5	0.0	0.0
Alaska.																															
Juneau	80	11	49	29.72	29.81	.....	37.0	.....	50	1	41	22	14	33	15	35	32	84	5.65	.....	18	3,600	e.	24	ne.	27	5	4	21	7.6	5.9	1.7

TABLE 2.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during November, 1920, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	10			0.68														0.40			
Albany, N. Y.	2			0.95														0.36			
Alpena, Mich.	1-2			1.20														*			
Amarillo, Tex.	7			0.87														0.58			
Anniston, Ala.	27			1.00														0.38			
Asheville, N. C.	27			0.60														0.26			
Atlanta, Ga.	15			1.48														0.25			
Atlantic City, N. J.	17			0.97														0.70			
Augusta, Ga.	16			2.38														0.61			
Baker, Oreg.	16-17			0.21														*			
Baltimore, Md.	16-17			2.83														0.30			
Bentonville, Ark.	8			0.17														0.12			
Binghamtom, N. Y.	16-17			1.16														0.18			*
Birmingham, Ala.	2			0.51														0.38			
Bismarck, N. Dak.	27			0.22														*			
Block Island, R. I.	17			1.24														0.33			
Boise, Idaho.	19			0.28														0.18			
Boston, Mass.	23			1.89														0.46			
Buffalo, N. Y.	16-17			2.82														*			
Burlington, Vt.	16-17			0.68														*			
Cairo, Ill.	1			0.30														0.11			
Canton, N. Y.	17			0.96														*			
Charles City, Iowa.	5-6			1.20														*			
Charleston, S. C.	27			0.69														0.35			
Charlotte, N. C.	27			0.80														0.42			
Chattanooga, Tenn.	10			0.49														0.25			
Cheyenne, Wyo.	11			0.17														*			
Chicago, Ill.	1			0.26														0.11			
Cincinnati, Ohio.	21			0.40														0.26			
Cleveland, Ohio.	16-17			0.66														*			
Columbia, Mo.	29			0.22														0.10			
Columbia, S. C.	27			0.86														0.35			
Columbus, Ohio.	2			0.34														0.18			
Concord, N. H.	2-3			0.98														*			
Concordia, Kans.	6			0.62														0.23			
Corpus Christi, Tex.	25-26			0.75														*			
Dallas, Tex.	26			1.07														0.33			
Davenport, Iowa.	1			0.78														0.23			
Dayton, Ohio.	22			1.54														0.22			
Del Rio, Tex.	10			0.11														0.09			
Denver, Colo.	11-12			0.07														*			
Des Moines, Iowa.	6			0.58														*			
Detroit, Mich.	22-23			0.71														*			
Devils Lake, N. Dak.	27-28			0.55														*			
Dodge City, Kans.	6			0.73														0.29			
Drexel, Nebr.	6			1.18														0.35			
Dubuque, Iowa.	6			0.72														*			
Duluth, Minn.	8			0.72														*			
Eastport, Me.	3			0.35														0.17			
Elkins, W. Va.																					
Ellendale, N. Dak.	8			0.39														0.08			
El Paso, Tex.	7-12-25			T.														T.			
Erie, Pa.	16-17			1.49														*			
Escanaba, Mich.	1			0.66														0.16			
Eureka, Calif.	16			1.97														0.34			
Evansville, Ind.	1			0.74														0.24			
Flagstaff, Ariz.																					
Fort Smith, Ark.	1			0.14														0.14			
Fort Wayne, Ind.	22			0.64														*			
Fort Worth, Tex.	26			0.79														0.24			
Fresno, Calif.	15			0.64														0.13			
Galveston, Tex.	1	5:17 p. m.	6:39 p. m.	0.68	5:22 p. m.	5:41 p. m.	0.01	0.21	0.35	0.45	0.53										
Grand Haven, Mich.	11			0.44														*			
Grand Junction, Colo.	7			0.28														0.10			
Grand Rapids, Mich.	8			0.19														0.07			
Green Bay, Wis.	21-22			1.33														*			
Greenville, S. C.	16			1.93														0.34			
Hannibal, Mo.	29			0.46														0.24			
Harrisburg, Pa.	16			1.34														0.26			
Hartford, Conn.	22-23	9:00 p. m.	8:15 a. m.	2.07	6:41 a. m.	7:00 a. m.	1.39	0.15	0.32	0.41	0.52										
Hatteras, N. C.	27-28			1.66														0.34			
Havre, Mont.	8			0.07														*			
Helena, Mont.	8			0.15														*			
Houghton, Mich.	10			0.94														*			
Houston, Tex.	1	9:57 a. m.	10:55 a. m.	0.84	9:57 a. m.	10:23 a. m.	0.00	0.09	0.15	0.44	0.64	0.79	0.84								
		12:05 p. m.	4:15 p. m.	2.36	1:42 p. m.	2:57 p. m.	0.35	0.20	0.26	0.27	0.36	0.45	0.46	0.67	1.04	1.35	1.38	1.74	1.95		
Huron, S. Dak.	1			0.59														*			
Independence, Calif.	6-7			0.05														*			
Indianapolis, Ind.	1			1.08														0.43			
Iola, Kans.	6			0.60														0.46			
Jacksonville, Fla.	15-16	10:17 a. m.	1:30 p. m.	2.72	10:15 a. m.	11:19 a. m.	1.36	0.06	0.14	0.21	0.34	0.41	0.52	0.62	0.70	0.84	0.97	1.19	1.30		
Kalispell, Mont.	19			0.15														0.12			
Kansas City, Mo.	6			1.12														0.35			
Keokuk, Iowa.	29			0.45														0.14			
Key West, Fla.	27			0.47														0.44			
Knoxville, Tenn.	27			1.09														0.31			
La Crosse, Wis.	21			1.16														*			
Lander, Wyo.	5-6			1.14														*			
Lansing, Mich.	22			0.79														*			
Lewiston, Idaho.	19			0.20														0.11			
Lexington, Ky.	22			0.68														0.16			
Lincoln, Nebr.	6			0.58														0.28			
Little Rock, Ark.	26			0.32														0.16			
Los Angeles, Calif.	6			0.64														0.36			
Louisville, Ky.	21			1.46														0.49			
Ludington, Mich.	21			0.63														0.30			
Lynchburg, Va.	28			1.62														0.42			
Macon, Ga.	16			2.10														0.46			
Madison, Wis.	21			0.25														0.17			
Marquette, Mich.	1			0.67														0.18			

* Self-register not in use.

TABLE 2.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during November, 1920, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 mun.	60 min.	80 min.	100 min.	120 min.
Memphis, Tenn.	1			0.82														0.39			
Meridian, Miss.	2			0.87														0.57			
Miami, Fla.	27	5:26 p.m.	6:50 p.m.	1.78	5:30 p.m.	6:24 p.m.	0.02	0.13	0.20	0.25	0.32	0.42	0.48	0.49	0.53	0.57	0.67	0.86	1.76		
Milwaukee, Wis.	21			0.07														0.07			
Minneapolis, Minn.	1			0.40														0.15			
Mobile, Ala.	14–15			1.14														0.30			
Modena, Utah	12			0.09														0.06			
Montgomery, Ala.	2			0.40														0.22			
Moorhead, Minn.	8			0.25														*			
Mount Tamalpais, Calif.	18			1.13														0.38			
Nantucket, Mass.	23			1.55														0.35			
Nashville, Tenn.	27			0.88														0.26			
New Haven, Conn.	23			1.76														0.67			
New Orleans, La.	26			1.17														0.53			
New York, N. Y.	23			0.68														0.34			
Norfolk, Va.	28			1.05														0.24			
Northfield, Vt.	17			1.06														*			
North Head, Wash.	16			1.36														0.42			
North Platte, Nebr.	7–8			0.03														0.01			
Oklahoma, Okla.	7			1.71														0.52			
Omaha, Nebr.	28–29			0.62														*			
Oswego, N. Y.	16–17			1.86														*			
Palestine, Tex.	10			1.67														0.55			
Parkersburg, W. Va.	16			0.62														0.15			
Pensacola, Fla.	27			0.72														0.35			
Peoria, Ill.	1			0.55														0.22			
Philadelphia, Pa.	17			0.79														0.47			
Phoenix, Ariz.	5			T.														T.			
Pierre, S. Dak.	1			0.42														*			
Pittsburgh, Pa.	22			0.40														0.18			
Pocatello, Idaho.	26			0.60														0.30			
Point Reyes Light, Calif.	18			1.16														0.16			
Port Angeles, Wash.	26			0.65														0.15			
Port Huron, Mich.	2			0.52														0.12			
Portland, Me.	23			1.68														0.28			
Portland, Oreg.	17			1.48														0.29			
Providence, R. I.	23			1.28														0.61			
Pueblo, Colo.	12–13			0.21														*			
Raleigh, N. C.	15–16	D.N.p.m.	D.N.p.m.	3.93	6:24 p.m.	7:44 p.m.	2.42	0.07	0.11	0.20	0.29	0.34	0.37	0.43	0.54	0.66	0.75	0.86	1.20		
Rapid City, S. Dak.	20			0.18														*			
Reading, Pa.	17			0.65														0.28			
Red Bluff, Calif.	26			1.26														0.29			
Reno, Nev.	11–12			0.33														*			
Richmond, Va.	2			0.87														0.60			
Rochester, N. Y.	1			0.62														0.17			
Roseburg, Oreg.	19			0.71														0.28			
Roswell, N. Mex.	11–12			0.14														0.03			
Sacramento, Calif.	18			0.58														0.30			
Saginaw, Mich.	21			0.17														0.15			
St. Joseph, Mo.	6			1.57														0.43			
St. Louis, Mo.	1			0.24														0.13			
St. Paul, Minn.	1			0.37														*			
Salt Lake City, Utah	20			0.57														*			
San Antonio, Tex.	26			0.98														0.58			
San Diego, Calif.	7			0.10														0.06			
Sand Key, Fla.	27			0.60														0.58			
Sandusky, Ohio.	2			0.69														0.25			
Sandy Hook, N. J.	23			0.92														0.55			
San Francisco, Calif.	15			0.65														0.14			
San Jose, Calif.	7–8			0.64														*			
San Luis Obispo, Calif.	15			0.61														0.16			
Santa Fe, N. Mex.	12–13			0.07														*			
Sault Ste. Marie, Mich.	4			0.44														*			
Savannah, Ga.	11	12:45 a.m.	12:20 p.m.	2.74	7:13 a.m.	7:37 a.m.	1.53	0.10	0.27	0.38	0.52	0.60									
Scranton, Pa.	16–17			0.86														*			
Seattle, Wash.	17			0.66														0.25			
Sheridan, Wyo.	27			0.17														*			
Shreveport, La.	27			0.31														0.25			
Sioux City, Iowa.	28			0.51														0.07			
Spokane, Wash.	17			0.32														0.08			
Springfield, Ill.	7			0.21														*			
Springfield, Mo.	8			0.17														0.08			
Syracuse, N. Y.	22–23			1.30														*			
Tacoma, Wash.	19			0.35														0.21			
Tampa, Fla.	16			0.90														0.63			
Tatoosh Island, Wash.	25			0.68														0.42			
Taylor, Tex.	26			1.24														0.48			
Terre Haute, Ind.	29			0.14														0.10			
Thomasville, Ga.	2			0.66														0.58			
Toledo, Ohio.	2			0.63														0.41			
Tonopah, Nev.	15			0.24														*			
Topeka, Kans.	6			1.20														0.40			
Trenton, N. J.	22			0.77														0.27			
Valentine, Nebr.	1			0.19														*			
Vicksburg, Miss.	1			0.69														0.37			
Walla Walla, Wash.	22			0.41														0.21			
Washington, D. C.	16			2.17														0.29			
Wausau, Wis.	21–22			1.25														*			
Wichita, Kans.	6			1.56														0.36			
Williston, N. Dak.	8			0.04														*			
Wilmington, N. C.	16			2.03														0.77			
Winnemucca, Nev.	12			0.27														0.15			
Wytheville, Va.	28			0.93														0.35			
Yankton, S. Dak.	8			0.18														*			
Yellowstone Park, Wyo.	5–6			0.23														*			

* Self-register not in use.

TABLE 3.—*Data furnished by the Canadian Meteorological Service, November, 1920.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.72	29.86	−.08	32.3	−4.2	37.4	27.3	56	15	5.09	−0.48	4.0
Sydney, C. B. I.	48	30.00	30.05	+0.10	35.3	−1.8	41.2	29.3	59	17	4.11	−1.33	11.5
Halifax, N. S.	88	29.96	30.07	+.06	36.2	−1.1	43.8	28.6	60	18	5.02	−0.64	1.4
Yarmouth, N. S.	65	29.98	30.05	+.03	38.2	−1.7	44.8	31.6	61	21	4.25	−0.31	3.3
Charlottetown, P. E. I.	38	30.00	30.04	+.08	33.4	−2.1	38.9	28.0	60	19	2.69	−1.28	9.9
Chatham, N. B.	28	30.05	30.08	+.11	29.7	−1.3	37.2	22.2	60	0	2.95	−0.80	9.2
Father Point, Que.	20	30.04	30.06	+.10	25.7	−3.2	32.4	19.1	45	4	1.99	−1.12	12.1
Quebec, Que.	296	29.78	30.12	+.10	27.4	−1.6	32.5	22.4	44	6	2.11	−1.65	12.1
Montreal, Que.	187	29.89	30.11	+.10	31.4	−0.4	36.5	26.4	50	12	2.61	−1.13	10.9
Stonecliffe, Ont.	489	29.45	30.08	+.07	24.2	−4.9	35.7	12.7	46	−4	2.11	−0.47	9.9
Ottawa, Ont.	236	29.84	30.12	+.10	31.7	0.0	38.2	25.3	52	13	3.24	+0.70	15.5
Kingston, Ont.	285	29.78	30.10	+.06	35.4	+0.4	41.4	29.5	55	15	3.70	+0.46	23.5
Toronto, Ont.	379	29.69	30.11	+.07	36.7	+1.1	42.0	31.5	62	20	3.80	+0.66	10.9
Cochrane, Ont.	930												
White River, Ont.	1,244	28.71	30.07	+.09	21.7	+1.2	31.5	12.0	45	−8	0.67	−1.18	6.7
Port Stanley, Ont.	592	29.40	30.06	+.11	37.6	+0.8	44.2	31.0	60	16	8.26	+4.89	19.1
Southampton, Ont.	656	29.35			35.6	+0.6	41.0	30.3	54	6	4.39	+0.69	12.2
Parry Sound, Ont.	688	29.39	30.00	−.01	33.4	+1.3	39.7	27.1	54	8	2.93	−1.44	4.1
Port Arthur, Ont.	644	29.38	29.98	−.02	27.8	+3.8	34.1	21.5	42	−1	0.56	−0.77	1.6
Winnepeg, Man.	760	29.25	30.12	+.08	25.2	+7.2	32.7	17.8	47	0	1.50	+0.42	11.3
Minnedosa, Man.	1,690	28.22	30.10	+.06	24.1	+6.8	30.8	17.4	48	0	0.79	−0.21	6.8
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.75	30.06	+.06	25.2	+6.4	32.4	18.1	46	−9	0.66	−0.23	3.4
Medicine Hat, Alb.	2,144												
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.44	30.17	+.15	28.4	+5.2	37.3	19.6	54	−8	0.22	−0.47	0.9
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450	28.46	30.09	+.06	23.9	+8.5	31.7	16.2	50	0	0.87	+0.04	6.5
Battleford, Sask.	1,592	28.25	30.04	+.02	28.6	+10.3	34.4	18.8	55	2	0.22	−0.36	T.
Kamloops, B. C.	1,262	28.82	30.15	+.19	36.6	+3.2	43.0	30.1	52	11	0.78	0.68	T.
Victoria, B. C.	230	29.75	30.00	+.01	46.0	+2.8	50.5	41.6	58	35	3.11	−3.86	0.0
Barkerville, B. C.	4,180	25.59	29.97	+.07	27.7	+4.1	34.3	21.0	42	6	2.66	−0.63	21.0
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Bermuda	151	29.99	30.15	+.10	70.7	+2.0	76.3	65.1	82	58	3.80	−0.58	0.0

SEISMOLOGY.*

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Jan. 3, 1921.]

TABLE 1.—*Noninstrumental earthquake reports, November, 1920.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		MAINE.								
1919.	*H. m.*		° ′	° ′			*Sec.*			
Nov. 9	0 40	Eastport	45 00	67 00	4	1	2	Loud rumbling	Felt at several other towns in State also.	G. Brown.
		OREGON.								
9	20 20	Portland	45 30	122 40	3	1	5	None	Felt by many	E. H. Jones.
28	11 43	Portland	45 30	122 40	3	1	3	.....do	.....do	F. D. Young.
		WASHINGTON.								
28	11 33	Longmire	46 50	121 50	4	1	35	Rumbling	Felt at Paradise Inn also	J. B. Flett.
	11 40	Detroit	47 20	122 50	3	2	10	None	Felt by one	W. O. Eckert.
		UTAH.								
20	5 40	Brigham	41 30	112 00	6	1	30	Rumbling	Felt by many	J. N. Andersen.
25	24 00	St. George	37 05	113 30	6	1	60	.....do	Felt by everyone	R. U. Macfarlane.

TABLE 2.—*Instrumental seismological reports, November, 1920.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significancance of symbols see REVIEW for January 1920, pp. 62-63.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
CALIFORNIA. *Theosophical University, Point Loma.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 6	.....	.....	.....	.....	100	100	.....	Tremors.
8	.....	.....	.....	.....	50	50	.....	
10	.....	.....	.....	.....	100	100	.....	
12	.....	.....	.....	.....	100	100	.....	
14	.....	.....	.....	.....	100	100	.....	
15	.....	.....	.....	.....	100	100	.....	
21	.....	.....	.....	.....	50	100	.....	
23	.....	.....	.....	.....	100	150	.....	
24	.....	.....	.....	.....	50	100	.....	
27	.....	.....	.....	.....	100	100	.....	
28	.....	.....	.....	.....	100	100	.....	
30	.....	.....	.....	.....	100	100	.....	
COLORADO. *Sacred Heart College, Denver.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 2	.....	L_N	2 51 —	.....	.....	.....	.....	
		F_N	2 58 —	.....	.....	.....	.....	
13	.....	L_N	1 29 —	.....	.....	.....	.....	Wavelets and thickening of penmarks.
		F_N	1 37 —	.....	.....	.....	.....	
16	.....	.....	.....	.....	.....	.....	.....	Activity and visible wavelets on NS.
20	.....	L_N	24 39 —	.....	.....	.....	.....	
		M_N	24 42 —	7–10	*500	*500	.....	P not visible; hardly any record on EW.
		C_N	24 46 —	.....	.....	.....	.....	
		F_N	24 49 —	.....	.....	.....	.....	
20	.....	L_N	2 36 —	.....	.....	.....	.....	P not visible; no record on EW.
		F_N	2 42 —	.....	.....	.....	.....	
29	.....	L_N	21 26 —	.....	.....	.....	.....	Somewhat doubtful as to being seismic.
		F_N	21 32 —	.....	.....	.....	.....	

* Trace amplitude.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
DISTRICT OF COLUMBIA. *Georgetown University, Washington.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 4	.....	e	2 16 00	.....	.....	.....	.....	Very heavy micros.
		S	2 20 05	.....	.....	.....	.....	
		L	2 28 11	9	.....	.....	.....	
		F	2 40 —	.....	.....	.....	.....	
6	.....	e_E	10 53 40	.....	.....	.....	.....	
		e_N	10 53 44	.....	.....	.....	.....	
		eL_E	10 59 24	11	.....	.....	.....	
		eL_N	10 59 42	14	.....	.....	.....	
		F	11 10 —	.....	.....	.....	.....	
12	.....	e_E	5 57 27	.....	.....	.....	.....	Heavy micros; NS does not show.
		L_E	6 09 22	21	.....	.....	.....	
		F	6 20 —	.....	.....	.....	.....	
16	.....	P_E	8 38 55	.....	.....	.....	.....	NS out of order.
		eL_E	8 46 36	.....	.....	.....	.....	
		F	9 30 —	.....	.....	.....	.....	
28	.....	e	11 42 36	.....	.....	.....	.....	Heavy micros.
		S?	11 48 58	.....	.....	.....	.....	
		F	12 30 —	.....	.....	.....	.....	
29	.....	P_E	8 11 44	.....	.....	.....	.....	Heavy micros.
		S_E	8 18 45	.....	.....	.....	.....	Difficult to interpret.
		eL_E?	8 24 00	.....	.....	.....	.....	
		F	9 20 —	.....	.....	.....	.....	
DISTRICT OF COLUMBIA. *U. S. Weather Bureau Washington.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 4	.....	P	2 15 10	.....	.....	.....	2,300	
		S	2 19 00	.....	.....	.....	.....	
		eL	2 22 00	.....	.....	.....	.....	
		F	2 40 ..	.....	.....	.....	.....	
6	.....	P	10 48 44	.....	.....	.....	2,500	
		S	10 52 48	.....	.....	.....	.....	
		eL	10 57 ..	.....	.....	.....	.....	
		L	10 59 ..	16	.....	.....	.....	
		F	11 15 *ca.*	.....	.....	.....	.....	
12	.....	S	6 00 02	.....	.....	.....	3,300	
		L	9 00 00	24	.....	.....	.....	
		F	9 25 00	.....	.....	.....	.....	
16	.....	P	8 38 55	.....	.....	.....	4,000	
		PR1	8 40 30	.....	.....	.....	.....	
		S	8 44 37	.....	.....	.....	.....	
		eL?	8 51 00	.....	.....	.....	.....	
		M_E	8 53 40	.....	*19,000	.....	.....	
		F	9 30 *ca.*	.....	.....	.....	.....	
28	.....	e	11 45 50	.....	.....	.....	.....	
		M	11 49 10	.....	*1,500	*1,500	.....	
		F	12 10 ..	.....	.....	.....	.....	
29	.....	P	.....	.....	.....	.....	.....	Lost in heavy micros.
		S	8 19 08	.....	.....	.....	.....	Times uncertain.
		eL	8 23 ..	.....	.....	.....	.....	
		M	8 29 30	.....	*9,000	*9,000	.....	
		F	.....	.....	.....	.....	.....	Lost in micros. The Valdez-Sitka, Valdez-Cordova, and Valdez-Seward cables were broken by an earthquake at 10:03 p. m., 150th meridian time, Nov. 28.

*Trace amplitude.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
ILLINOIS. *U. S. Weather Bureau, Chicago.*								
1920.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Nov. 1	.....	eL_E	17 55 50	22	.....	.....	.....	
		F	18 30 *ca.*	.....	.....	.....	.....	
4	.....	P	2 17 47	.....	.....	.....	2,300	
		S	2 21 23	.....	.....	.....	.....	
		L?	2 23 10	.....	.....	.....	.....	
		L	2 26 30	18	.....	.....	.....	
		F	2 50 *ca.*	.....	.....	.....	.....	
6	.....	P	10 51 15	.....	.....	.....	.....	
		S	10 55 56	.....	.....	.....	.....	
		L	10 58 50	.....	.....	.....	.....	
		L	11 01 45	16	.....	.....	.....	
		F	11 40 *ca.*	.....	.....	.....	.....	
6	.....	eL	22 11 ..	.....	.....	.....	.....	
		L	22 16 30	18	.....	.....	.....	
		F	22 30 *ca.*	.....	.....	.....	.....	
12	.....	S	6 03 00	.....	.....	.....	7,000	P lost in micros.
		L	6 14 40	22	.....	.....	.....	
		L	6 20 ..	18	.....	.....	.....	
		F	7 20 *ca.*	.....	.....	.....	.....	
16	.....	P	8 39 15	.....	.....	.....	3,600	
		S	8 44 41	.....	.....	.....	.....	
		L	8 47 50	16	.....	.....	.....	
		M	8 52 30	.....	*8,500	*8,500	.....	
		F	10 20 *ca.*	.....	.....	.....	.....	
20	.....	eL	7 43 40	.....	.....	.....	.....	
		F	7 50 *ca.*	.....	.....	.....	.....	
26	.....	eL	9 25 50	33	.....	.....	.....	
		L	9 28 ..	24	.....	.....	.....	
		L	9 37 ..	16	.....	.....	.....	
		F	10 20 *ca.*	.....	.....	.....	.....	
28	.....	P	11 37 40	.....	.....	.....	2,800	
		S	11 42 04	.....	.....	.....	.....	
		L	11 45 17	.....	.....	.....	.....	
		F	12 30 ..	.....	.....	.....	.....	
29	.....	P	8 12 27	.....	.....	.....	4,000	
		PR1	8 13 24	.....	.....	.....	.....	
		S	8 18 15	.....	.....	.....	.....	
		L	8 21 07	16	.....	.....	.....	
		F	9 30 *ca.*	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, November, 1920*—Continued.

NEW YORK. *Cornell University, Ithaca.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 4	.....	e.....	2 16 40	3	.....	.....	.....	
		iP.....	2 16 50	4	.....	.....	.....	
		S.....	2 20 50	.....	.....	.....	.....	
		F.....	2 37 ..	.....	.....	.....	.....	
16	.....	i_N.....	8 38 25	3	.....	.....	.....	Clock error uncertain.
		S?.....	8 44 10	5	.....	.....	.....	
		e.....	8 46 40	5	.....	.....	.....	
		L.....	8 51 05	6	.....	.....	.....	
		F.....	9 18 ..	.....	.....	.....	.....	
28	.....	eL.....	11 47 ..	7	.....	.....	.....	
		F.....	11 57 ..	.....	.....	.....	.....	
29	.....	P?.....	8 18 13	5	.....	.....	.....	
		S?.....	8 23 56	4	.....	.....	.....	
		L.....	8 27 15	7	.....	.....	.....	
		F.....	8 49 ..	.....	.....	.....	.....	

CANAL ZONE. *Panama Canal, Balboa Heights.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 13	.....	P_E.....	1 46 46	.....	.....	.....	298	Direction probably W. or SW.
		P_N.....	1 46 48	.....	.....	.....	.....	
		S_E.....	1 47 18	.....	.....	.....	.....	
		S_N.....	1 47 20	.....	.....	.....	.....	
		M_E.....	1 47 36	.....	*3,500	.....	.....	
		M_N.....	1 47 32	.....	.....	*1,800	.....	
		F_E.....	1 50 40	.....	.....	.....	.....	
		F_N.....	1 51 10	.....	.....	.....	.....	

* Trace amplitude.

VERMONT. *U. S. Weather Bureau, Northfield.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 4	.....	eL.....	2 21 20	.....	.....	.....	.....	
		F.....	2 24 ca.	.....	.....	.....	.....	
16	.....	e.....	8 44 30	.....	*1,000	*1,000	.....	
		M.....	8 51 40	.....	.....	.....	.....	
		F.....	9 10 ca.	.....	.....	.....	.....	
28	.....	e.....	11 48 ..	.....	.....	.....	.....	
		F.....	12 ca.	.....	.....	.....	.....	
29	.....	e.....	8 21 ..	.....	.....	.....	.....	
		L.....	8 24 ..	10	.....	.....	.....	
		F.....	8 45 ca.	.....	.....	.....	.....	

* Trace amplitude.

CANADA. *Dominion Observatory, Ottawa.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 4	.....	e.....	2 21 40	Irreg.	.....	.....	.....	Lost in micros.
		F.....	2 45 ..	.....	.....	.....	.....	
6	.....	e_E.....	10 55 47	.....	.....	.....	.....	NS lost in micros.
		eL_E...	11 00 21	.....	.....	.....	.....	
		L_E.....	11 08 31	12	.....	.....	.....	
		F.....	11 15 ..	.....	.....	.....	.....	
8	.....	e.....	19 26 00	.....	.....	.....	.....	Reported from St. Thomas de Joliette, Quebec.
		e.....	19 27 33	.....	.....	.....	.....	
12	.....	e.....	6 00 33	.....	.....	.....	.....	
		eL.....	6 07 17	.....	.....	.....	.....	
		L.....	6 11 ..	20	.....	.....	.....	
		F.....	6 40 ..	.....	.....	.....	.....	
16	.....	O.....	8 30 54	.....	.....	.....	3,960	
		iP.....	8 38 09	.....	.....	.....	.....	
		S.....	8 43 54	.....	.....	.....	.....	
		eL_E...	8 48 32	Irreg.	.....	.....	.....	
		L_E.....	8 49 23	32	.....	.....	.....	
		F.....	9 35 ..	.....	.....	.....	.....	
		SASKATOON RECORD.						
		eP.....	8 35 08	.....	.....	.....	2,510	
		iS.....	8 39 14	.....	.....	.....	.....	
		L.....	8 41 ca.	.....	.....	.....	.....	
26	.....	eL.....	9 24 00	20–14	.....	.....	.....	
		F.....	9 50 ..	.....	.....	.....	.....	
28	.....	eL.....	11 46 54	.....	.....	.....	.....	Irregular L waves of small amplitude.
		F.....	12 18 ..	.....	.....	.....	.....	
29	.....	O.....	8 05 10	.....	.....	.....	3,740	
		eP_E...	8 12 09	.....	.....	.....	.....	
		S.....	8 17 41	.....	.....	.....	.....	
		eL.....	8 20 52	23	.....	.....	.....	
		L.....	8 35 ..	12	.....	.....	.....	
		F.....	9 00 ..	.....	.....	.....	.....	

CANADA. *Dominion Meteorological Service, Toronto.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 4	.....	L.....	2 22 18	.....	*200	.....	.....	
		L.....	2 27 36	.....	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	Micros.
6	.....	e.....	10 54 54	.....	.....	.....	.....	
		L.....	10 58 24	.....	.....	.....	.....	
		eL.....	11 00 36	.....	.....	.....	.....	
		M.....	11 02 18	.....	*300	.....	.....	
		F.....	11 24 54	.....	.....	.....	.....	
8	.....	.....	.....	.....	.....	.....	.....	Small micros going on at intervals throughout day; feeble shocks reported from Joliette, Que., at 20h. 25m. G.M.T. Window frames trembled.
12	.....	e.....	6 02 00	.....	.....	.....	.....	
		L.....	6 11 48	.....	.....	.....	.....	
		eL.....	6 13 54	.....	.....	.....	.....	
		M.....	6 18 36	.....	*400	.....	.....	
		F.....	6 38 42	.....	.....	.....	.....	
16	.....	S.....	?8 44 12	.....	.....	.....	.....	P not recorded; S indistict.
		eL.....	8 47 12	.....	.....	.....	.....	
		iL.....	8 50 30	.....	.....	.....	.....	
		M.....	8 51 18	.....	*1,200	.....	.....	
		F.....	9 35 36	.....	.....	.....	.....	
26	.....	eL.....	9 33 30	.....	.....	.....	.....	
		M.....	9 34 36	.....	*200	.....	.....	
		F.....	9 54 54	.....	.....	.....	.....	
28	.....	L.....	11 46 54	.....	.....	.....	.....	
		F.....	11 57 54	.....	*200	.....	.....	
29	.....	S.....	8 18 00	.....	.....	.....	3,450	From L–S.
		eL.....	8 21 18	.....	.....	.....	.....	
		eL.....	8 22 48	.....	.....	.....	.....	
		eL.....	8 28 24	.....	.....	.....	.....	
		eL.....	8 30 06	.....	.....	.....	.....	
		M.....	8 30 48	.....	*300	.....	.....	
		F.....	8 51 18	.....	.....	.....	.....	

* Trace amplitude.

CANADA. *Dominion Meteorological Service, Victoria.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Nov. 12	.....	P.....	6 06 10	.....	.....	.....	5,190?	
		S?.....	6 13 03	.....	.....	.....	.....	
		L.....	6 25 20	.....	.....	.....	.....	
		M.....	6 32 43	.....	*500	.....	.....	
		F.....	6 54 50	.....	.....	.....	.....	
16	.....	P.....	8 36 20	.....	.....	.....	2,380	
		S.....	8 40 15	.....	.....	.....	.....	
		L.....	8 43 12	.....	.....	.....	.....	
		M.....	8 44 11	.....	*2,500	.....	.....	
		eL.....	8 45 31	.....	.....	.....	.....	
		F.....	9 14 11	.....	.....	.....	.....	
		VERTICAL.						
		P.....	8 36 20	3	.....	.....	2,600	
		S.....	8 40 40	6	.....	.....	.....	
		L.....	8 44 15	6	.....	.....	.....	
		M.....	8 47 15	20	3	.....	.....	
26	.....	L.....	?9 39 51	.....	.....	.....	.....	
		M.....	9 41 50	.....	*300	.....	.....	
		F.....	?9 46 17	.....	.....	.....	.....	
28	.....	P.....	11 30 48	.....	.....	.....	.....	In Washington State; felt in Seattle, Spokane; probably south of Victoria.
		L.....	11 31 32	.....	.....	.....	330	
		M.....	11 31 47	.....	*1,300	.....	.....	
		F.....	11 43 05	.....	.....	.....	.....	
		VERTICAL.						
		P.....	11 30 53	2	.....	.....	260	
		L.....	11 31 26	3	.....	.....	.....	
		M.....	11 31 41	5	36	.....	.....	
		F.....	11 40 00	.....	.....	.....	.....	
29	.....	P.....	8 06 46	.....	.....	.....	2,030	Alaska, near Kodiak.
		S.....	8 10 13	.....	.....	.....	.....	
		L.....	8 12 40	.....	.....	.....	.....	
		M.....	8 13 54	.....	*600	.....	.....	
		F.....	8 29 39	.....	.....	.....	.....	
		VERTICAL.						
		P.....	8 07 30	3	.....	.....	2,220	
		S.....	8 11 20	5	.....	.....	.....	
		M.....	8 11 40	.....	.....	3	.....	

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, November, 1920*—Contd.

No earthquakes were recorded at the following stations during November, 1920:

ALABAMA. *Spring Hill College, Mobile.*

Reports for November, 1920, have not been received from the following stations:

ALASKA. *U. S. C. & G. S. Magnetic Observatory*, Sitka.
ARIZONA. *U. S. C. & G. S. Magnetic Observatory*, Tucson.
HAWAII. *U. S. C. & G. S. Magnetic Observatory*, Honolulu.
KANSAS. *University of Kansas*, Lawrence.
MARYLAND. *U. S. C. & G. S. Magnetic Observatory*, Cheltenham
MASSACHUSETTS. *Harvard University*, Cambridge.
MISSOURI. *St. Louis University*, St. Louis.
NEW YORK. *Canisius College*, Buffalo; *Fordham University*, New York.
PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.

TABLE 3.—*Late reports (instrumental).*

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka. No earthquakes recorded during October, 1920.*

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Oct. 1	.....	e_N	18 54 25	4	.....	.....	.....	
		e_E	18 58 10	.....	.....	.....	.....	
		L_N	19 00 06	.....	.....	.....	.....	
		L_E	19 00 10	.....	.....	.....	.....	
		M_N	19 01 19	12	.....	190	.....	
		M_E	19 01 18	13	650	.....	.....	
		C_N	19 08 —	8	.....	.....	.....	
		C_E	19 04 —	9	.....	.....	.....	
		F_N	19 20 —	7	.....	.....	.....	
		F_E	19 22 —	8	.....	.....	.....	
8	.....	P_N	16 56 14	4	.....	.....	.....	
		eP_E	16 56 14	4	.....	.....	.....	
		S_N	16 59 59	.....	.....	.....	.....	
		S_E	16 59 57	5	.....	.....	.....	
		L_N	17 02 50	6	.....	.....	.....	
		L_E	17 02 53	7	.....	.....	.....	
		M_N	17 03 45	5	.....	50	.....	
		M_E	17 03 19	4	50	.....	.....	
		C_N	17 08 —	.....	.....	.....	.....	
		C_E	17 07 —	.....	.....	.....	.....	
		F_N	17 11 —	.....	.....	.....	.....	
		F_E	17 17 —	.....	.....	.....	.....	
18	.....	P_N	8 23 11	5	.....	.....	.....	Long waves not present.
		eP_E	8 23 12	.....	.....	.....	.....	
		iS_N	8 32 33	6	.....	.....	.....	
		S_E	8 32 40	6	.....	.....	.....	
		F_N	8 54 —	.....	.....	.....	.....	
		F_E	9 18 —	.....	.....	.....	.....	
22	.....	iP_N	12 20 47	5	.....	.....	.....	Long waves not clearly present.
		P_E	12 20 48	.....	.....	.....	.....	
		S_E	12 29 36	.....	.....	.....	.....	
		F_N	12 35 —	.....	.....	.....	.....	
		F_E	12 54 —	.....	.....	.....	.....	
28	.....	P_N	13 01 29	4	.....	.....	.....	
		eP_E	13 01 22	3	.....	.....	.....	
		S_E	13 10 35	.....	.....	.....	.....	
		eL_E	13 24 56	.....	10	.....	.....	
		F_N	13 19 —	.....	.....	.....	.....	
		F_E	13 38 —	.....	.....	.....	.....	

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Oct. 1	.....	e_N	19 01 05	.....	.....	.....	.....	
		e_E	19 09 35	.....	.....	.....	.....	
		L_N	19 12 05	.....	.....	.....	.....	
		M_N	19 14 30	10	.....	10	.....	
		F_N	19 40 —	.....	.....	.....	.....	
8	.....	P	16 56 48	.....	.....	.....	.....	L waves can not be separated from S waves.
		S_N	17 01 04	.....	.....	.....	.....	
		M_N	17 08 33	.....	.....	30	.....	
		C_N	17 18 —	.....	.....	.....	.....	
		F_N	17 29 —	.....	.....	.....	.....	
		F_E	17 18 —	.....	.....	.....	.....	
18	.....	iP_N	8 24 21	3	.....	.....	.....	L waves not present on E.
		P_E	8 24 21	3	.....	.....	.....	
		iS_N	8 34 49	.....	.....	190	.....	
		S_E	8 34 45	.....	50	.....	.....	
		eL_N	9 02 45	.....	.....	.....	.....	
		M_N	9 09 30	18	.....	10	.....	
		F_N	9 35 —	.....	.....	.....	.....	
		F_E	8 55 —	.....	.....	.....	.....	
22	.....	iP_N	12 20 02	3	.....	.....	.....	L waves not on E; and only few on N.
		eP_E	12 20 04	4	.....	.....	.....	
		S_N	12 28 10	12	.....	.....	.....	
		eS_E	12 28 18	.....	.....	.....	.....	
		$eL_N(?)$	12 39 40	.....	.....	.....	.....	
		F_N	13 09 —	.....	.....	.....	.....	
		F_E	12 35 —	.....	.....	.....	.....	
26	.....	e_N	19 19 20	.....	.....	.....	.....	Record difficult to interpret.
		eL_N	19 26 32	.....	.....	.....	.....	
		M_N	19 28 12	8	.....	10	.....	
		F_N	17 55 —	.....	.....	.....	.....	
28	.....	iP_N	13 00 55	3	.....	.....	.....	L waves not clearly present.
		eP_N	13 01 00	3	.....	.....	.....	
		S_N	13 10 03	.....	.....	.....	.....	
		S_E	13 10 18	.....	.....	.....	.....	
		F_N	13 36 —	.....	.....	.....	.....	
		F_E	13 17 —	.....	.....	.....	.....	

TABLE 3.—*Late reports (instrumental)*—Continued.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Oct. 1	.....	e.....	19 16 36	.....	.....	.....	.....	
		M.....	19 22 00	17	*100	.....	.....	
		F.....	19 29 ..	.....	.....	.....	.....	
3	.....	P.....	5 35 06	.....	.....	.....	.....	
		M.....	5 35 54	16	*300	.....	.....	
		F.....	5 59 ..	.....	.....	.....	.....	
7	.....	eP.....	21 03 18	18	.....	.....	.....	
		Pr.....	21 10 30	.....	.....	.....	.....	(eP) faint and uncertain.
		S.....	21 17 24	19	.....	.....	.....	
		L.....	21 35 54	21	.....	.....	.....	
		M.....	21 43 54	18	*200	.....	.....	
		C.....	21 50 ..	18	.....	.....	.....	
		F.....	23 12 ..	17	.....	.....	.....	
8	.....	e_N.....	17 10 00	.....	.....	.....	.....	This interpretation adopted after comparison with Tucson and Cheltenham.
		eL.....	17 18 00	.....	*100	.....	.....	
		F.....	17 25 ..	.....	.....	.....	.....	
10	.....	eL.....	20 28 48	.....	.....	.....	.....	Tremor.
		M.....	20 35 00	17	*100	.....	.....	
		F.....	20 39 ..	.....	.....	.....	.....	
15	.....	e.....	14 28 36	.....	.....	.....	.....	
		L.....	14 37 24	18	.....	.....	.....	
		M.....	14 47 42	16	*300	.....	.....	
		C.....	15 00 ..	.....	.....	.....	.....	
		F.....	15 57 ..	.....	.....	.....	.....	
18	.....	iP.....	8 20 18	15	.....	.....	.....	
		iS.....	8 27 18	17	.....	.....	.....	
		L.....	8 39 00	18	.....	.....	.....	
		M.....	8 45 48	17	*3,300	.....	.....	
		C.....	8 54 ..	17	.....	.....	.....	
		F.....	10 30 ..	17	.....	.....	.....	
20	.....	eP.....	10 13 24	18	.....	.....	.....	
		S.....	10 23 18	17	.....	.....	.....	
		eL.....	10 38 24	20	.....	.....	.....	
		M.....	10 59 06	18	*400	.....	.....	
		C.....	11 11 ..	19	.....	.....	.....	
		F.....	11 27 ..	18	.....	.....	.....	
20		e.....	19 57 06	.....	.....	.....	.....	Phases not clearly defined.
		e.....	20 00 00	.....	.....	.....	.....	
		eL.....	20 08 00	19	.....	.....	.....	
		M.....	20 14 48	17	*100	.....	.....	
		C.....	20 17 ..	.....	.....	.....	.....	
		F.....	20 24 ..	.....	.....	.....	.....	
22	.....	e.....	11 07 00	18	.....	.....	.....	End merged with the succeeding record.
		S.....	11 09 48	18	.....	.....	.....	
		L.....	11 18 56	18	.....	.....	.....	
		M.....	11 30 00	18	*200	.....	.....	
		C.....	11 33 ..	18	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	
22	.....	eP.....	12 22 54	.....	.....	.....	.....	(eP) faint and difficult to place.
		S.....	12 34 00	16	.....	.....	.....	
		L.....	12 54 36	22	.....	.....	.....	
		M.....	13 03 18	17	*500	.....	.....	
		C.....	13 06 ..	17	.....	.....	.....	
		F.....	15 03 ..	17	.....	.....	.....	
24	.....	eP.....	1 48 00	18	.....	.....	.....	(eP) faint and uncertain.
		S.....	1 54 30	19	.....	.....	.....	
		L.....	1 59 24	20	.....	.....	.....	
		M.....	2 01 12	19	*600	.....	.....	
		C.....	2 13 ..	18	.....	.....	.....	
		F.....	2 56 ..	18	.....	.....	.....	
28	.....	eP.....	7 32 00	15	.....	.....	.....	Interpretation not clear.
		L.....	7 38 12	15	.....	.....	.....	
		M.....	7 39 36	15	*400	.....	.....	
		C.....	8 02 ..	16	.....	.....	.....	
		F.....	9 01 ..	.....	.....	.....	.....	
28	.....	eP.....	13 03 12	.....	.....	.....	.....	
		S.....	13 13 54	.....	.....	.....	.....	
		L.....	13 35 00	.....	.....	.....	.....	
		M.....	13 39 24	17	*500	.....	.....	
		C.....	13 54 ..	.....	.....	.....	.....	
		F.....	14 10 ..	.....	.....	.....	.....	

* Trace amplitude.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1920.			H. m. s.	Sec.	μ	μ	Km.	
Oct. 2	.....	iP.....	15 47 48	.....	.....	.....	.....	Strongly felt at Vieques.
		L.....	15 47 52	.....	.....	.....	.....	
		M.....	15 47 53	.....	300	1,350	.....	Similar to two underground explosions.
		C_N.....	15 48 20	.....	.....	.....	.....	
		C_E.....	15 48 15	.....	.....	.....	.....	
		F.....	15 53 ..	.....	.....	.....	.....	
7	.....	L_E.....	21 08 05	.....	.....	.....	.....	
		M_E.....	21 09 03	14	30	.....	.....	
		F_E.....	21 21 ..	.....	.....	.....	.....	
8	.....	e_N.....	16 57 21	.....	.....	.....	.....	No definite maximum.
		e_E.....	17 00 57	13	10	.....	.....	
		F_E.....	17 11 ..	.....	.....	.....	.....	
22	.....	e_N.....	12 22 47	.....	.....	.....	.....	Times uncertain for this record.
		e_E.....	12 23 35	.....	.....	.....	.....	
		e_N.....	12 26 45	.....	.....	.....	.....	
		e_E.....	12 26 55	12	.....	.....	.....	
		M_N.....	12 26 53	.....	.....	50	.....	
		M_E.....	12 27 46	.....	50	.....	.....	
		F_N.....	12 40 ..	.....	.....	.....	.....	
		F_E.....	12 41 ..	.....	.....	.....	.....	
27	.....	i_P.....	11 45 21	.....	.....	.....	.....	End merged with following quake; seems to be local shock.
		L_E.....	11 45 50	.....	.....	.....	.....	
		M_N.....	11 46 10	.....	.....	440	.....	
		M_E.....	11 46 21	.....	320	.....	.....	
		C_N.....	11 49 30	.....	.....	.....	.....	
		C_E.....	11 50 00	5	.....	.....	.....	
27	.....	eP_N.....	11 54 10	.....	.....	.....	.....	Seems to be a local shock.
		P_E.....	11 54 08	.....	.....	.....	.....	
		M_N.....	11 54 57	.....	.....	190	.....	
		M_E.....	11 55 09	.....	225	.....	.....	
		C_N.....	11 57 37	.....	.....	.....	.....	
		C_E.....	11 58 44	6	.....	.....	.....	
		F_N.....	12 08 ..	.....	.....	.....	.....	
		F_E.....	12 12 ..	5	.....	.....	.....	
28	.....	e_N.....	12 58 41	.....	.....	.....	.....	Record scant and difficult to interpret.
		e_N.....	13 00 22	.....	.....	10	.....	
		e_E.....	13 05 06	.....	.....	.....	.....	
		i_E.....	13 08 48	.....	.....	.....	.....	
		M_E.....	13 09 40	.....	10	.....	.....	
		F_E.....	13 13 ..	.....	.....	.....	.....	
		F_N.....	13 16 ..	.....	.....	.....	.....	

Chart I. Hydrographs of Several Principal Rivers, November, 1920.

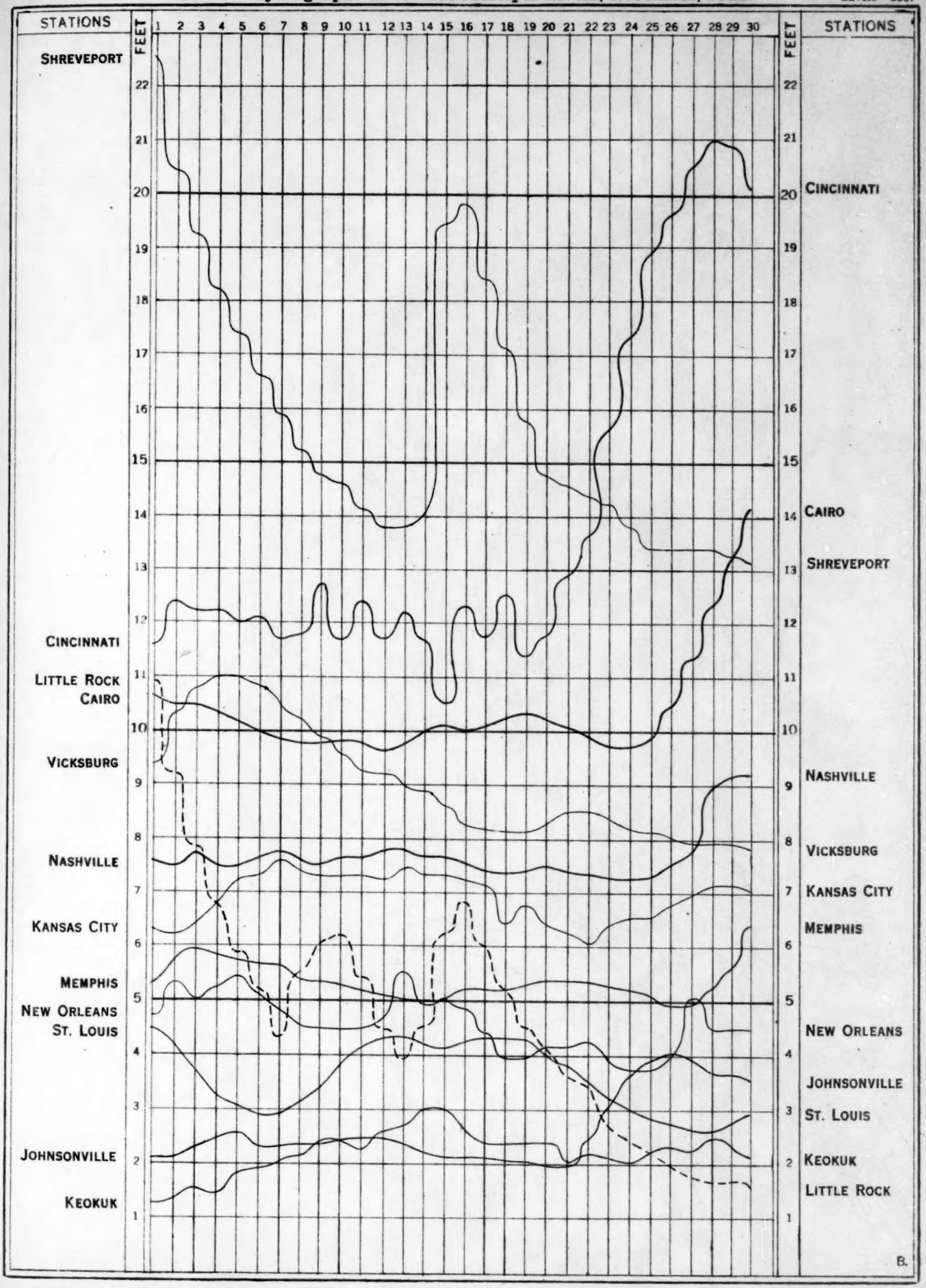


Chart II. Tracks of Centers of High Areas, November, 1920.

(Plotted by Wilfred P. Day.)

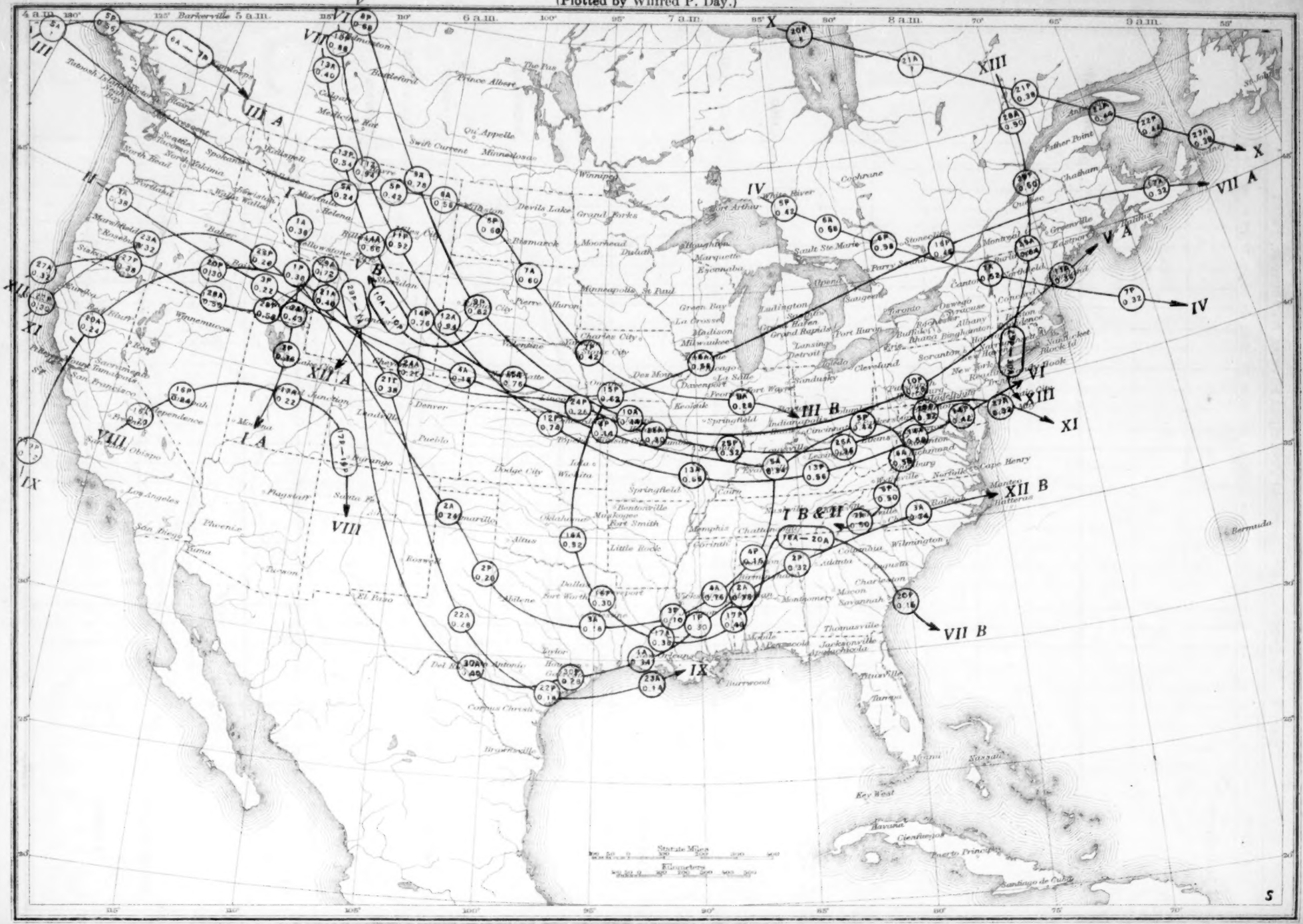


Chart III. Tracks of Centers of Low Areas, November, 1920.

(Plotted by Wilfred P. Day.)

Chart III. Tracks of Centers of Low Areas, November, 1920.

(Plotted by Wilfred P. Day.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, November, 1920.

Chart V. Total Precipitation, Inches, November, 1920.

Chart V. Total Precipitation, Inches, November, 1920.

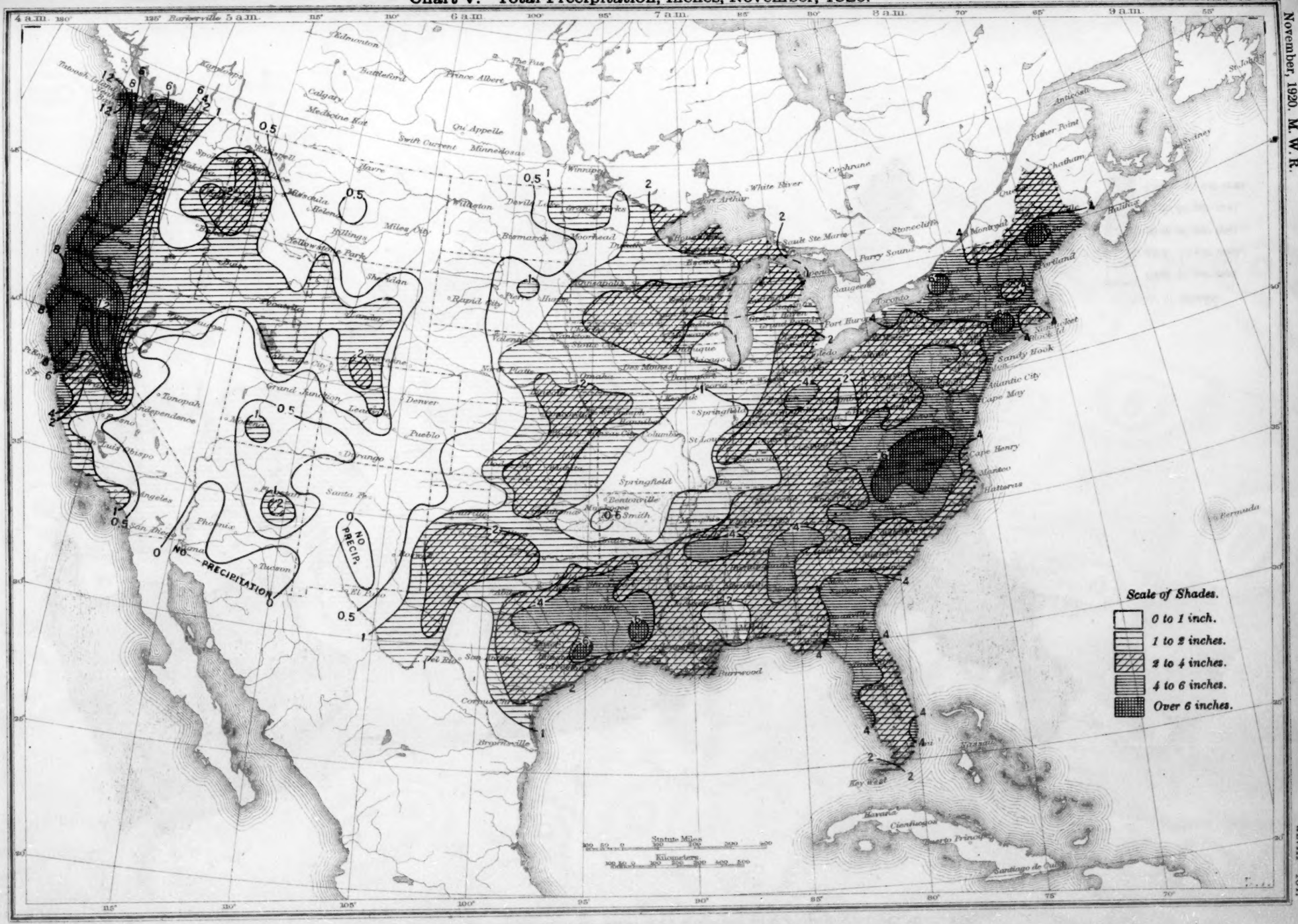


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, November, 1920.

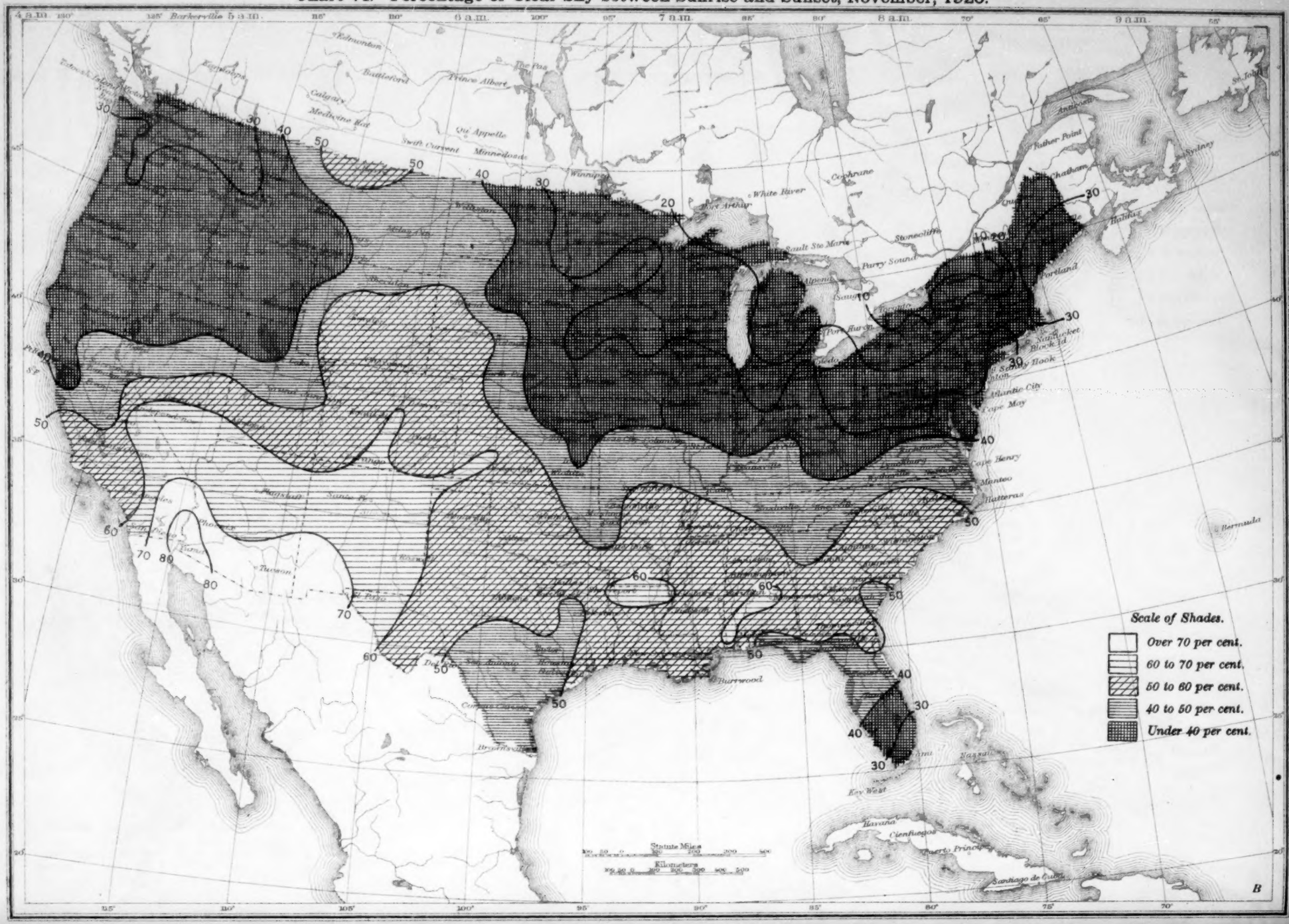


Chart VII. Isobars and Isotherms at Sea-level; Prevailing Winds, November, 1920.

Chart VII. Isobars and Isotherms at Sea-level; Prevailing Winds, November, 1920.

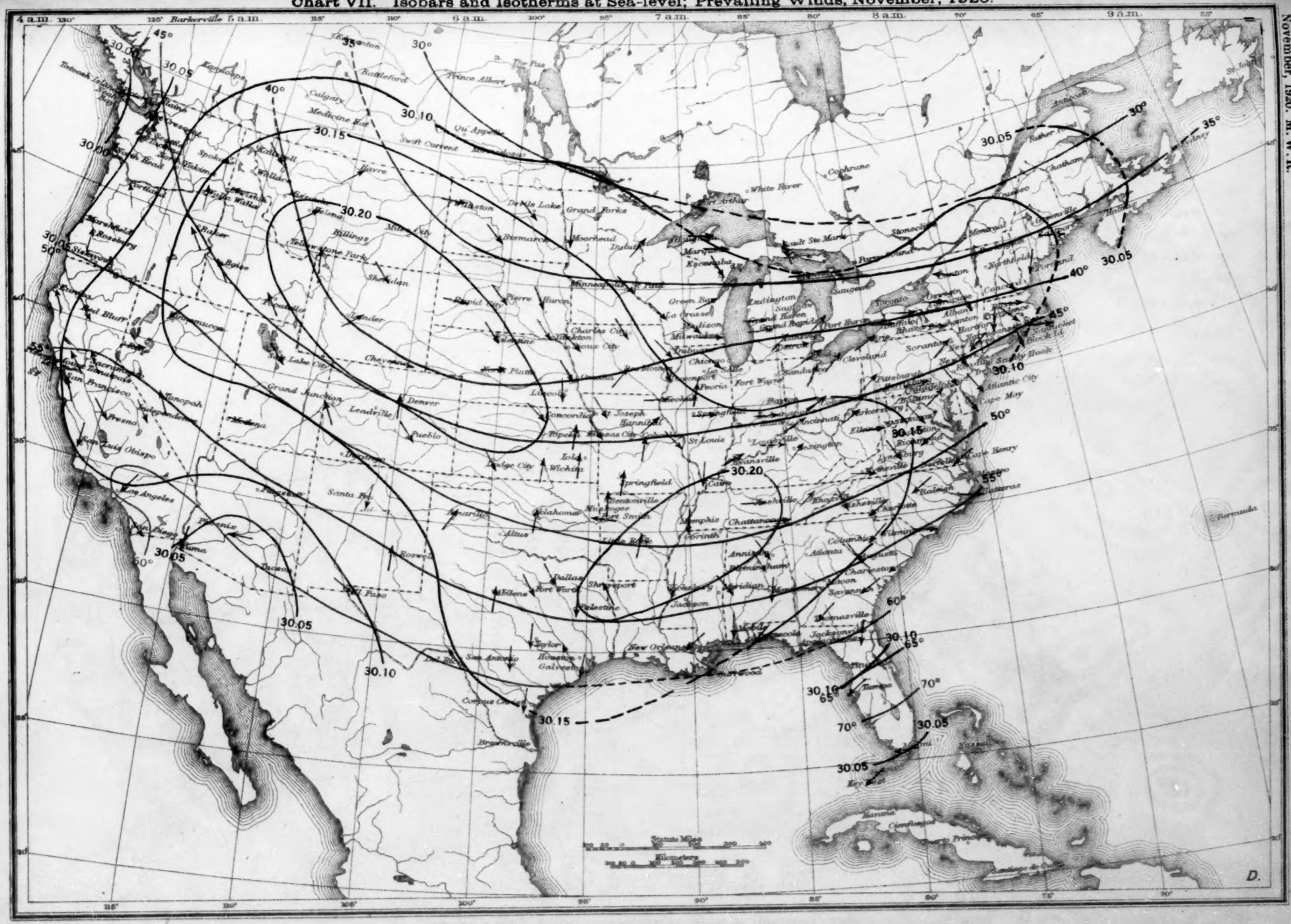


Chart VIII. Total Snowfall, Inches, November, 1920.

Chart IX. Weather Map of North Atlantic Ocean, November 13, 1920.

(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, November 13, 1920.

(Plotted by F. A. Young.)

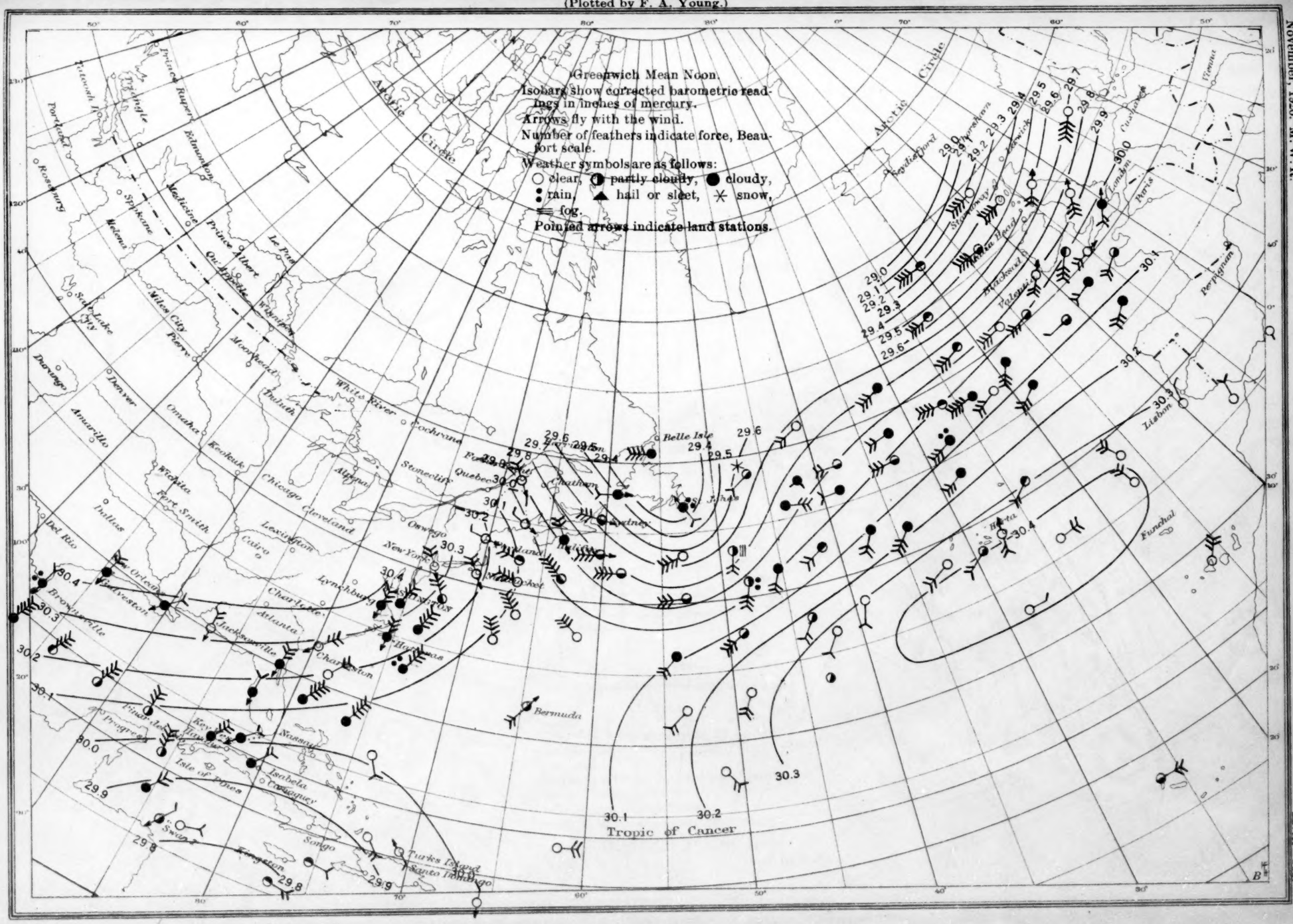

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Arctic Circle
Tropic of Cancer
Bermuda
Belle Isle
Halifax
Sydney
Quebec
Chatham
Portland
Buffalo
Toronto
Detroit
Cleveland
Chicago
Duluth
Omaha
Denver
Dodge City
Amarillo
Dallas
Fort Smith
Del Rio
Galveston
New Orleans
Jacksonville
Atlanta
Charleston
Lynchburg
Cairo
Lexington
Oswego
New York
Atlantic City
Hatteras
Nassau
Isle of Pines
Progreso
Swan
Kingston
Turks Island
Santo Domingo
Lisbon
Funchal
Paris
Perpignan
Blackpool
Valentia
Stornoway
Aberdeen
Lerwick
Thurso
Reykjavik
Jan Mayen
Godthaab
Angmagssalik
Prince Rupert
Edmonton
Medicine Hat
Prince Albert
Le Pas
Winnipeg
White River
Cochrane
Sault Ste. Marie
Moosonee
Swift Current
Moose Jaw
Calgary
Battleford
Qu'Appelle
Minnedosa
Swan River
Port Arthur
Parry Sound
Toronto
Kamloops
Nelson
Spokane
Walla Walla
Roseburg
Portland
Tatoosh I.
Tatoosh
Victoria
Seattle
Port Angeles
Tillamook
Salt Lake City
Ely
Winnemucca
Modena
Reno
Independence
Fresno
Santa Barbara
Los Angeles
San Diego
Yuma
Phoenix
Tucson
Roswell
Abilene
Fort Worth
Oklahoma
Kansas City
Concordia
Dodge City
Wichita
Topeka
Omaha
Rochester
Buffalo
Erie
Pittsburgh
Harrisburg
Philadelphia
Washington
Norfolk
Hatteras
Wilmington
Charleston
Savannah
Jacksonville
Tampa
Key West
Havana
Nassau
Isle of Pines
Progreso
Swan
Kingston
Turks Island
Santo Domingo
Bermuda
Belle Isle
Halifax
Sydney
Quebec
Chatham
Portland
Buffalo
Toronto
Detroit
Cleveland
Chicago
Duluth
Omaha
Denver

Chart X. Weather Map of North Atlantic Ocean, November 14, 1920.

(Plotted by F. A. Young.)

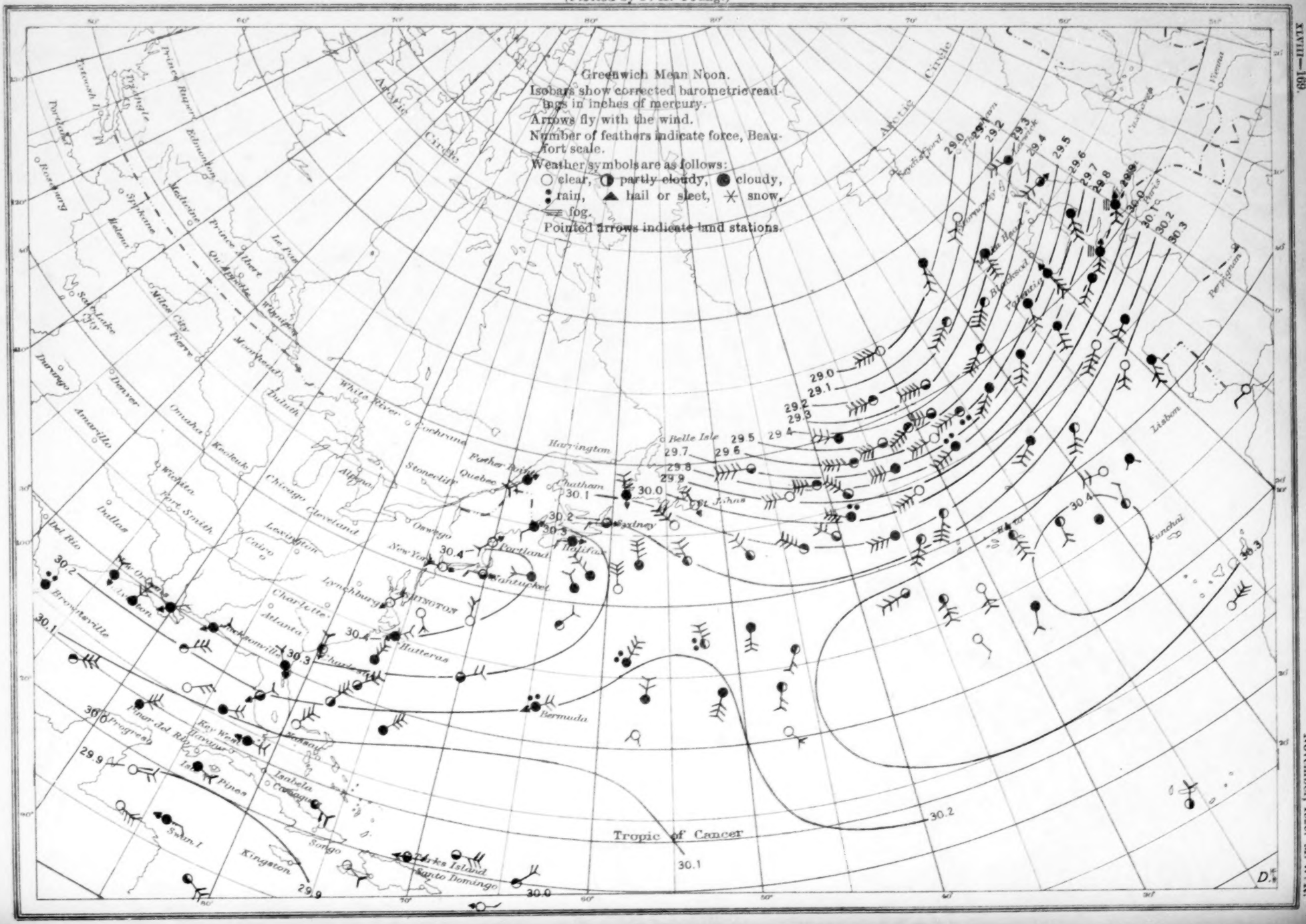


Chart XI. Weather Map of North Atlantic Ocean, November 17, 1920.

Chart XI. Weather Map of North Atlantic Ocean, November 17, 1920.

(Plotted by F. A. Young.)

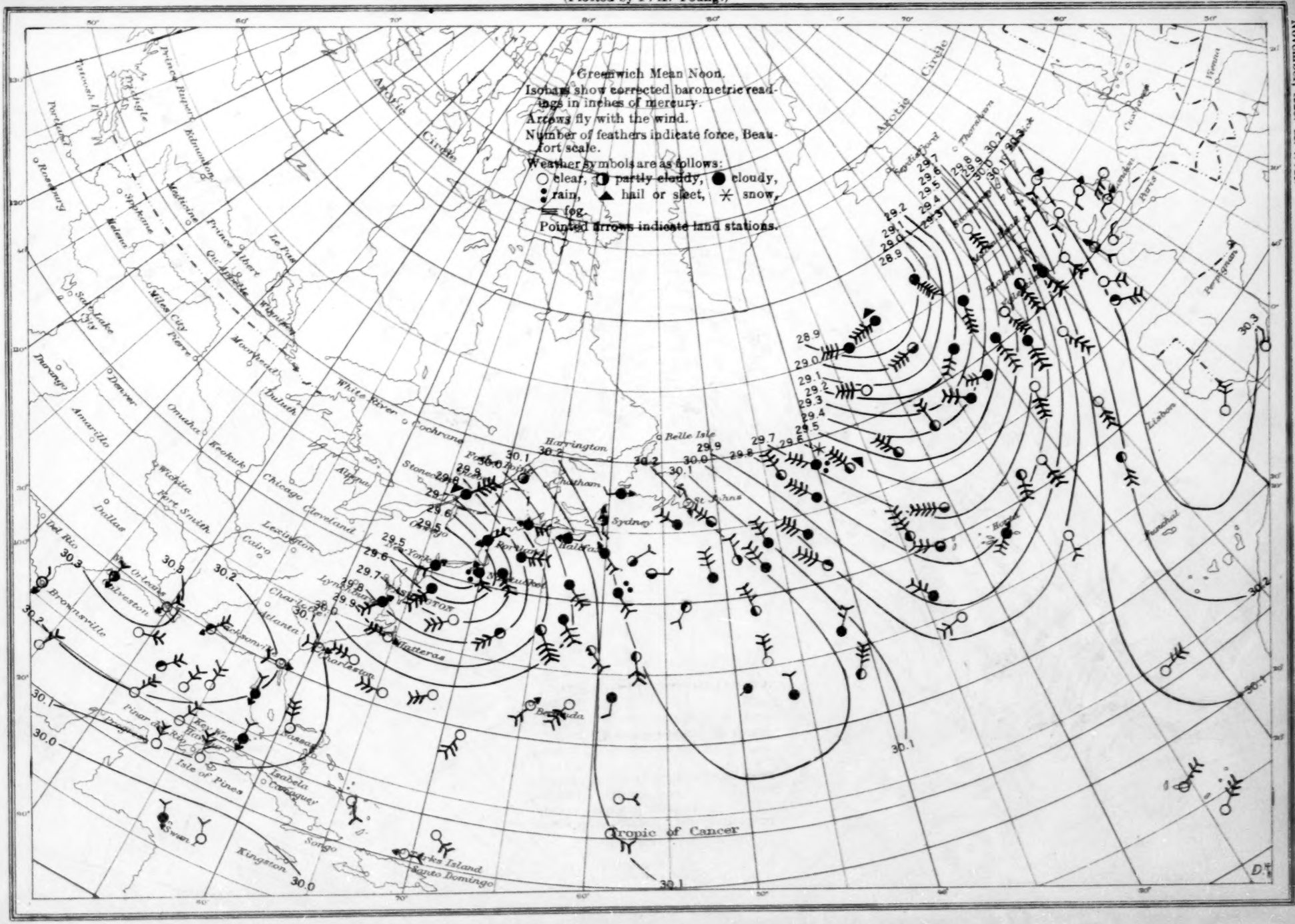


Chart XII. Weather Map of North Atlantic Ocean, November 18, 1920.

(Plotted by F. A. Young.)

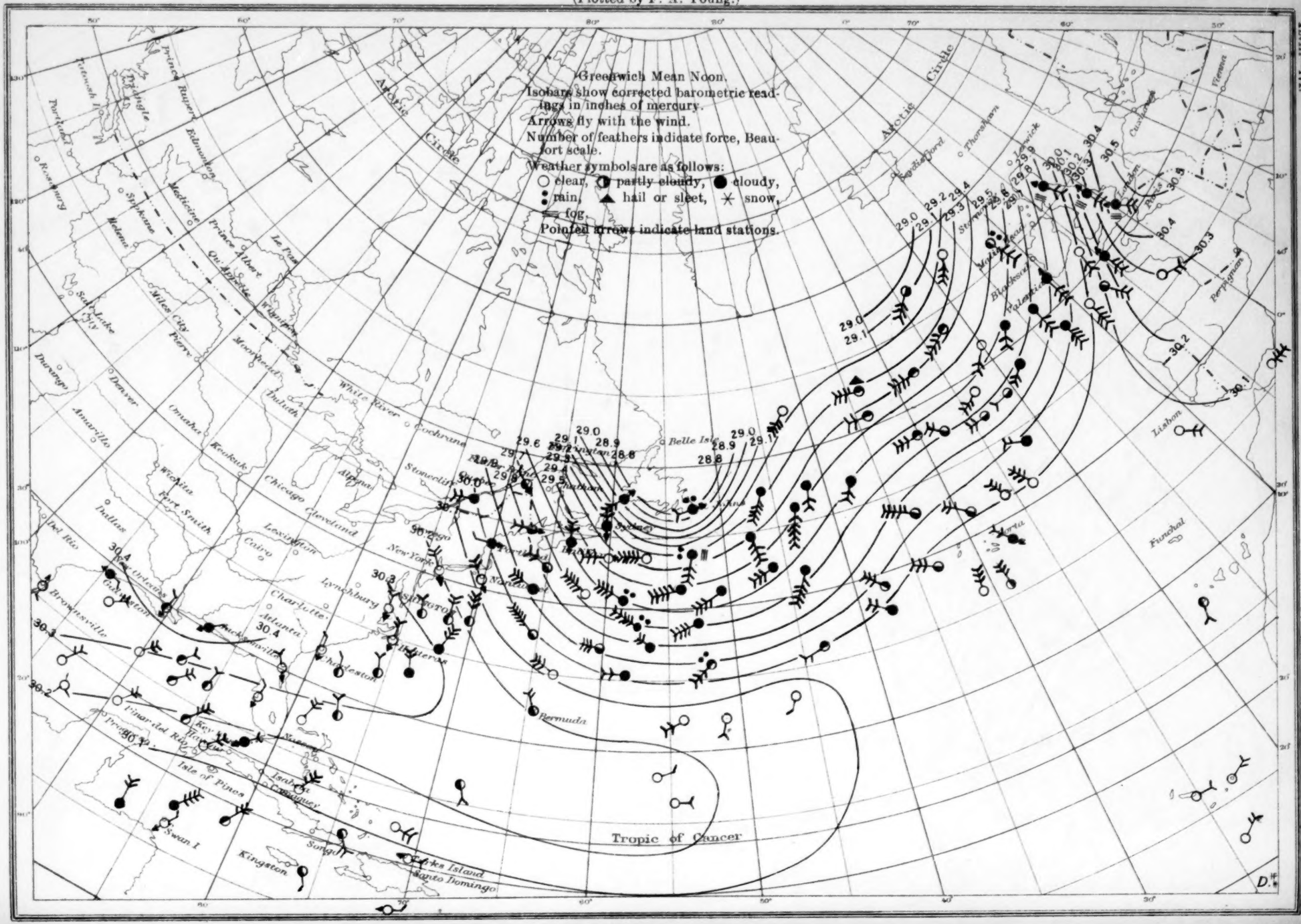

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Arctic Circle
Tropic of Cancer
Bermuda
Belle Isle
Lisbon
Funchal
Kingston
Santo Domingo
Swan I
Isle of Pines
Key West
Charleston
Atlanta
New Orleans
Galveston
Brownsville
Del Rio
Dallas
Fort Smith
Denver
Amarillo
Omaha
Chicago
Cleveland
Duluth
Pierre
Medicine Hat
Prince Albert
Winnipeg
Moosejaw
White River
Cochrane
Sherbrooke
Portland
Boston
Halifax
Sydney
Yarmouth
Quebec
Father Point
Port Arthur
Parry Sound
Toronto
Buffalo
Rochester
Albany
Pittsburgh
Cincinnati
Lexington
Cairo
Lynchburg
Charlotte
Wichita
Kansas City
Rockford
Minneapolis
Prince Rupert
Edmonton
Calgary
Swift Current
Medicine Hat
Moose Jaw
Prince Albert
Qu'Appelle
Winnipeg
Port Arthur
Father Point
Quebec
Yarmouth
Halifax
Sydney
Belle Isle
Thorshavn
Lerwick
Aberdeen
Stornoway
Valentia
Blacksod Bay
Galway
Roches Point
Scilly
Falmouth
Perpignan
Lisbon
Funchal
Tropic of Cancer
Bermuda

Chart XIII. Weather Map of North Atlantic Ocean, November 19, 1920.

(Plotted by F. A. Young.)

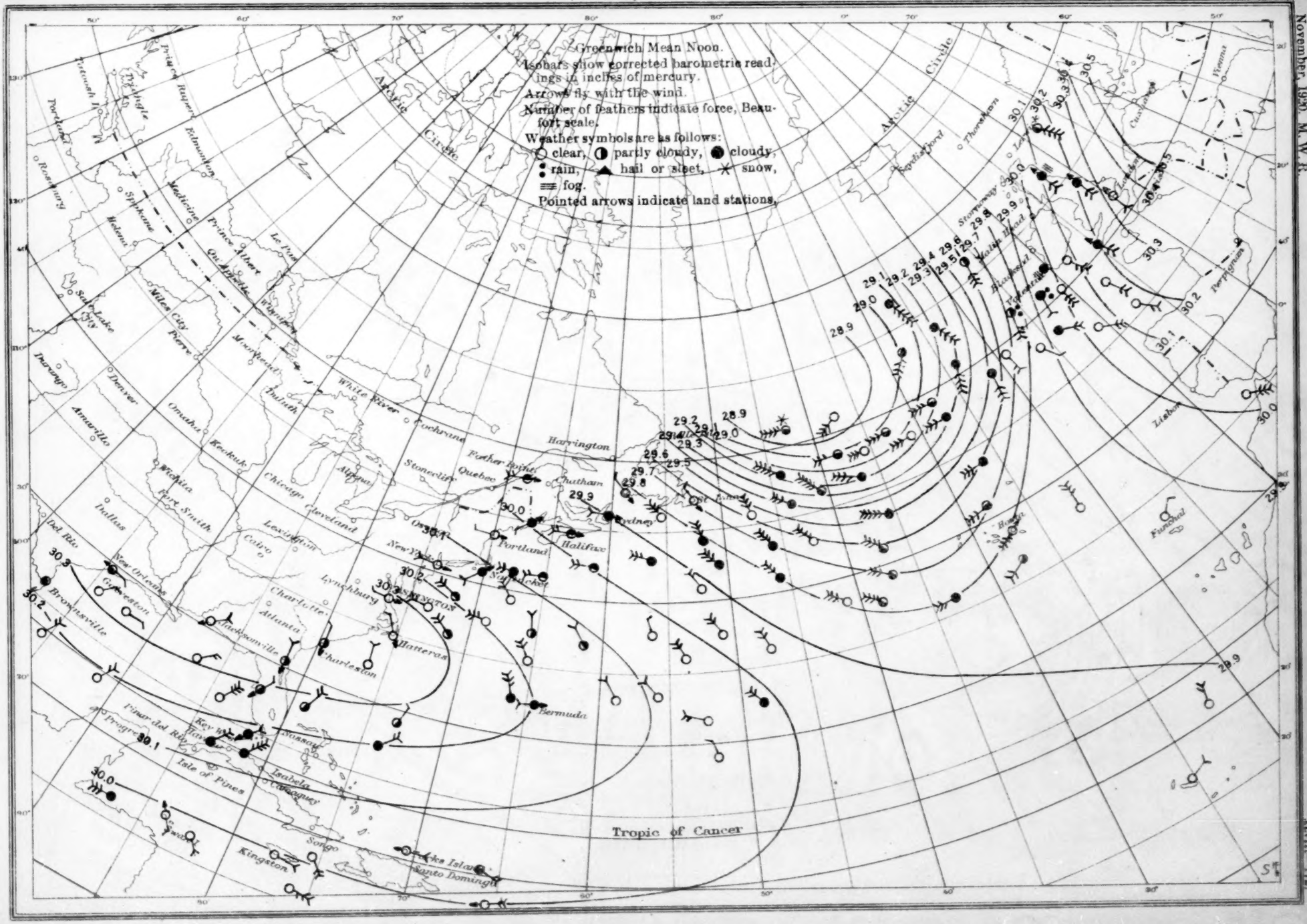
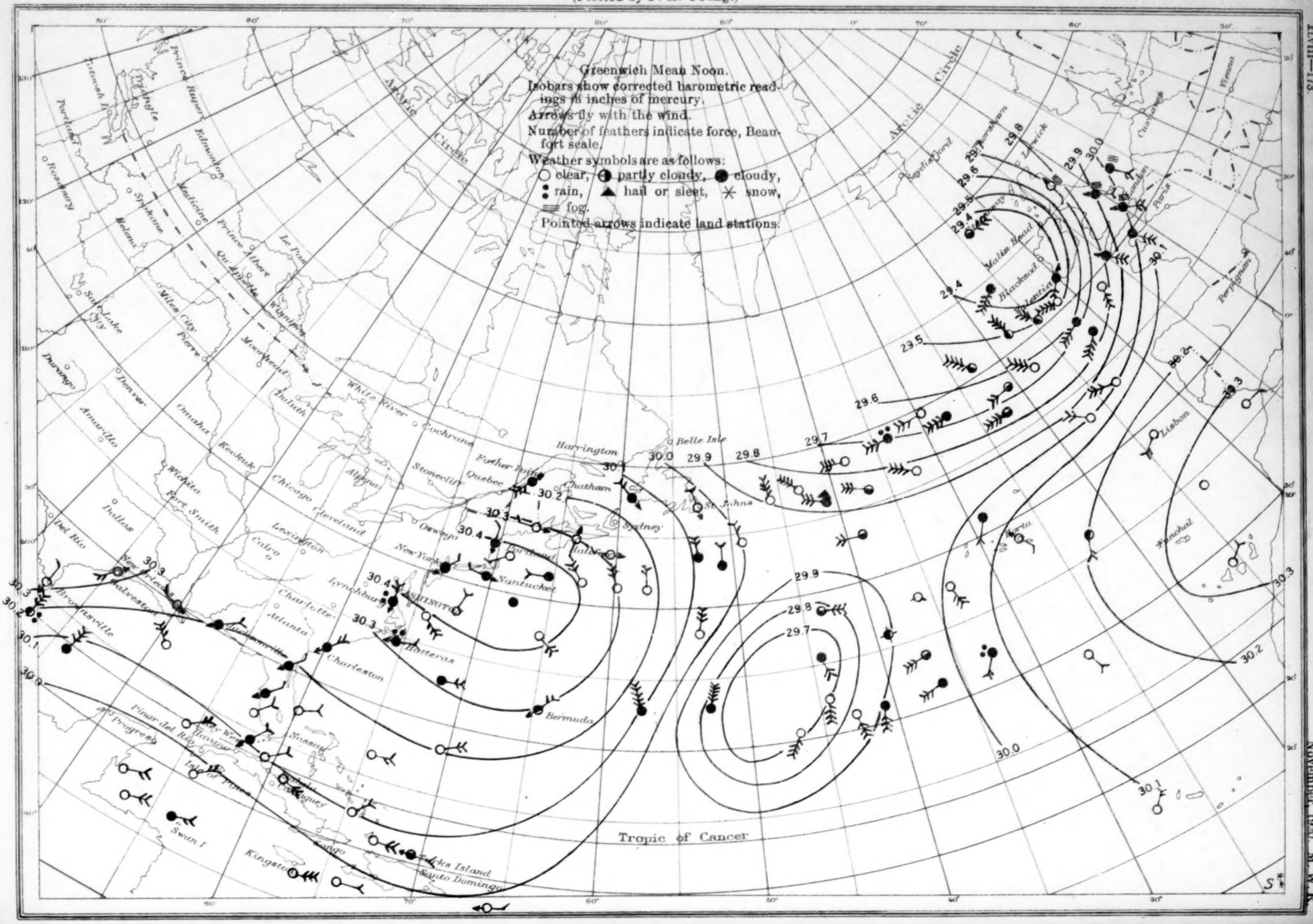
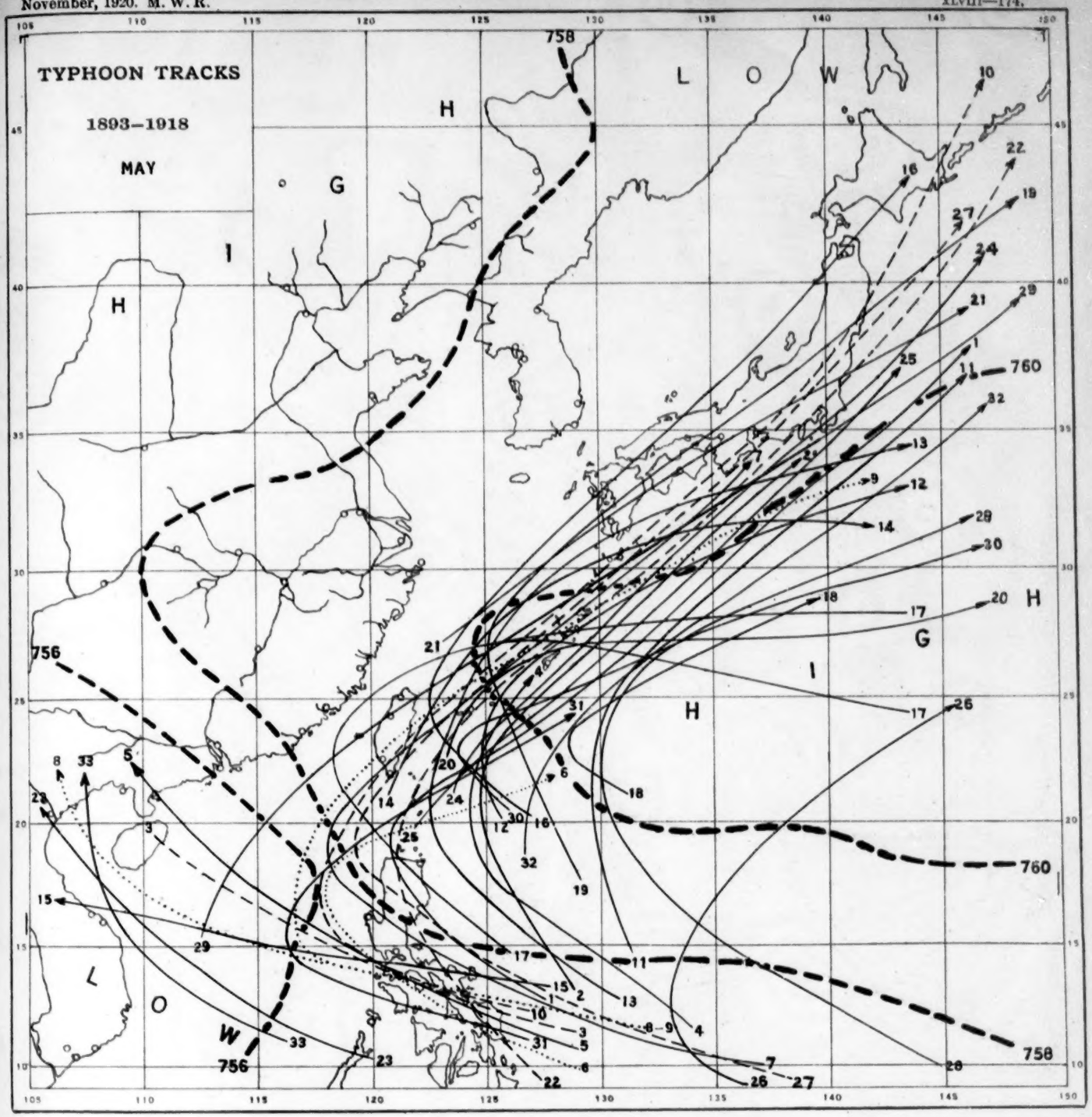


Chart XIV. Weather Map of North Atlantic Ocean, November 30, 1920.

(Plotted by F. A. Young.)





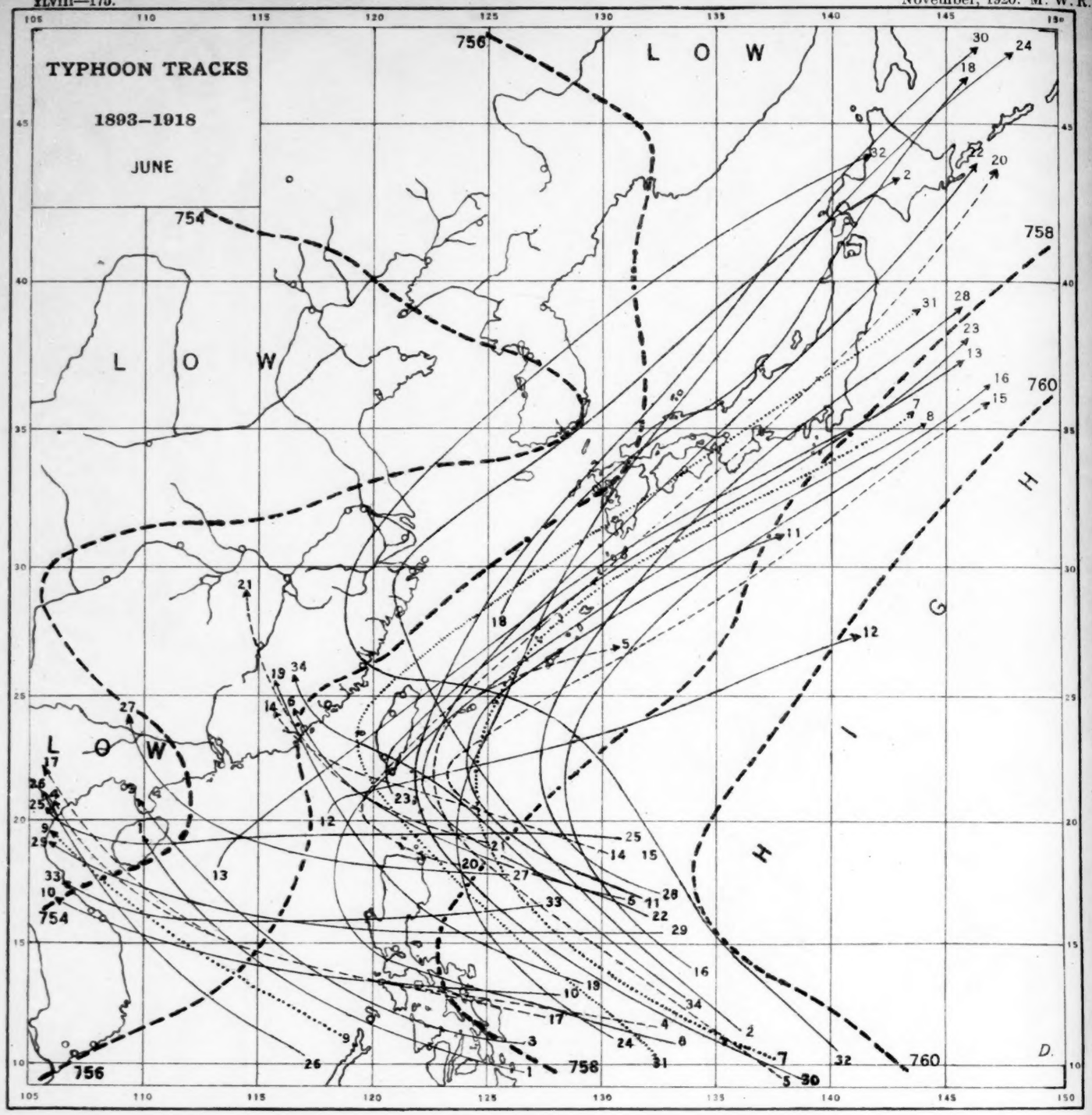
MAY.—*Single chart: 33 tracks; a little more than one case every year.*

Remarks.—A very significant change has taken place: while the number of the perturbations has more than doubled, their trajectories make a considerable bound towards the W, where their wanderings become easier for the reason that the great continental maximum is weakened and has retired a long way towards Siberia. The tracks begin to invade the Philippines and even the China Sea and after recurving towards the NE, form a dense bundle between Formosa and the Loochoos.

Several curves are turning on the China Sea, off western Luzon, not far from the Macclesfield bank; others have their recurving apex to the S. of the Meiaco-Sima group. The Sea of Japan and the Eastern Sea are still relatively free of their incursions, but a characteristic feature of the month is the invasion of the China Sea: no less than 6 typhoons, increasing in violence, are seen to strike the coast between Tourane and Kwang-chow-wan, crossing sometimes the Gulf of Tongking.

The birth-place of the storms has gained ground northwards and chiefly westwards: if we look to the converging point of the prolonged tracks, we see that they are mostly issued from the occidental Carolines, in the region of Yap. It is the opening of the true typhoons season.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]



JUNE.—*Single chart: 34 tracks; a little more than one case every year.*

Remarks.—The tropical storms have not much increased in numbers, but the translation of their movement towards the NW is asserting itself more and more. The Philippines are crossed freely, Hainan and the Gulf of Tongking receive more numerous visits, but the more interesting feature for us is that the coast of China is no more invulnerable; the typhoons may strike Kwangtung and even two instances give the warning that they can rise up to Foochow, and pay a visit, after recurving inland, to the mouth of the Yang-tze kiang.

The recurving of the trajectories takes place, with a fair degree of regularity, in the neighborhood of the Ballintang and the Bashi Channels about the 20th parallel, in the great curve of islands formed by the Meiaco-Simas, Formosa and northern Luzon. Thence the tracks are seen to start towards the NE. in great numbers, to sweep over the Loochoos, Kuishu and Nippon: a few begin even to cross the Sea of Japan.

The corresponding arrangement of the pressures deserves to be noticed: a distinct minimum has replaced the high plateau of the cold season on the Continent, as far as Mongolia, and on the other side, the maximum of the middle Pacific is throwing forward a spur that invades the Philippines. There is a striking parallelism between the so called "parabolas" of the typhoons and the isobaric lines surrounding the W end of the oceanic maximum.

[Reproduced from Atlas of the Tracks of 620 Typhoons, 1893–1918, by Louis Froc, S. J., Director Zi-ka-wei Observatory, Zi-ka-wei–Chang-hai, 1920.]